
WIRED
UK Edition!
BUILD YOUR OWN MILLENNIUM FALCON!*
MOORE'S LAW IS OVER!
MIKE LYNCH: $10BN MAN VS HACKERS!
HOW TO LIVE FOREVER!**
On a Mission!
SIMON PEGG
78 PRODUCTS WITH EXTRA WIREDNESS
Gear for Heroes
THE ESSENTIAL PRODUCT EDIT
*NOT TO SCALE
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AUG 15
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IDEAS | TECHNOLOGY | DESIGN | BUSINESS!

DRIVE RESPONSIBLY.

BMW i8, the most progressive sports car, has been named Best Eco Car at The Telegraph Cars Awards 2015. Combining sports car performance with ultra-low emissions, this hybrid re-defines the meaning of driving pleasure.

becomeelectric.co.uk/i8

Official fuel economy figures for the BMW i8: Weighted combined cycle: mpg 134.5 (2.1 l/100 km), CO_2 emissions 49 g/km, 62 miles/100 km (weighted combined cycle) 11.9 kWh, customer-orientated total range up to 373 miles. Maximum electric

BMW i

The Ultimate Driving Machine

power output (engine) 170/231 kW/hp, power output (electric motor) 96/131 kW/hp, total average energy consumption per range value 23 miles, common average electric range value (e-Drive only) up to 23 miles. Figures may vary depending on different factors.

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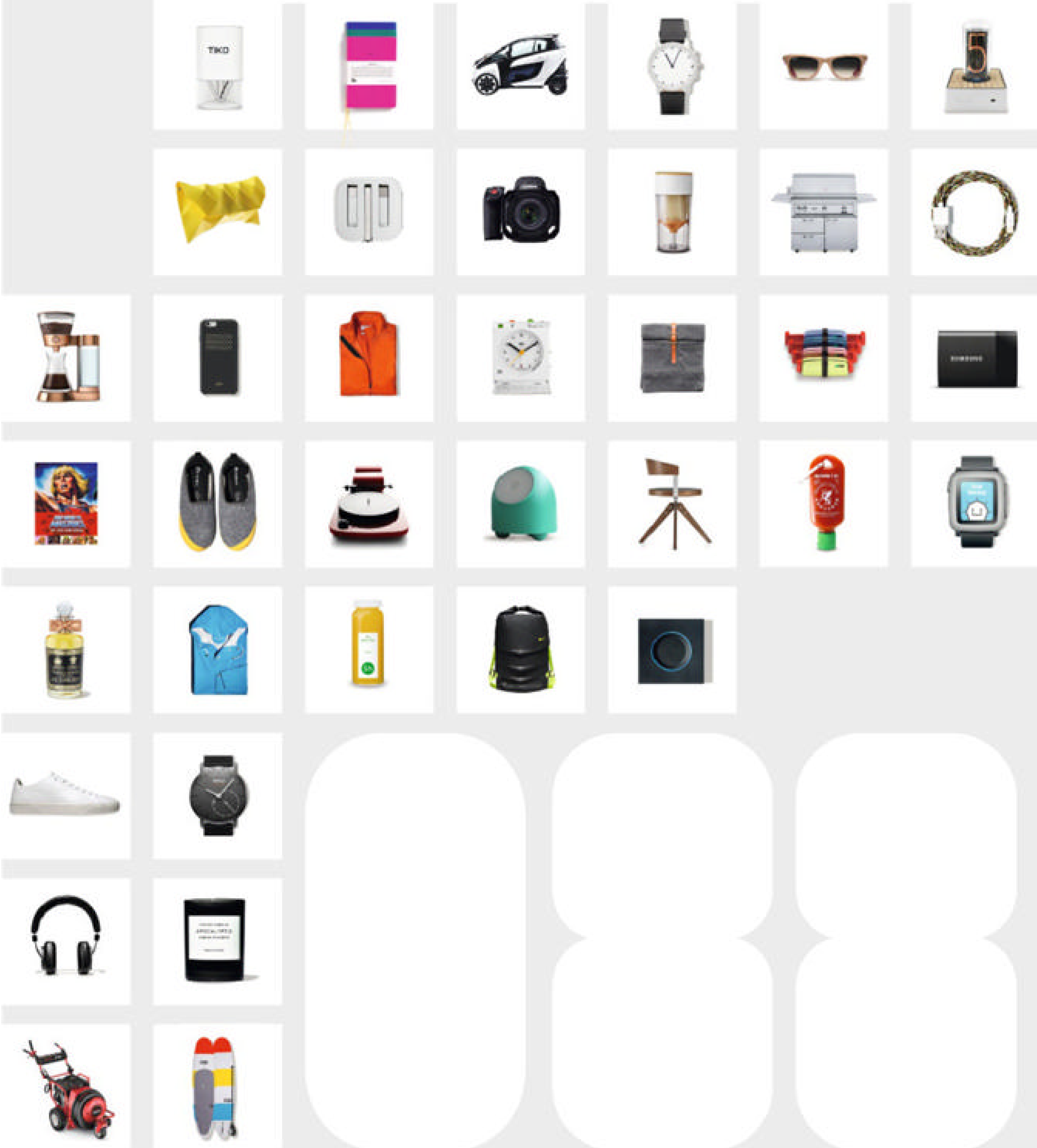
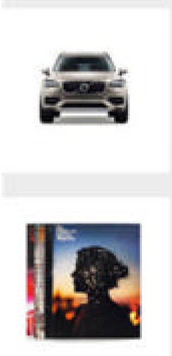
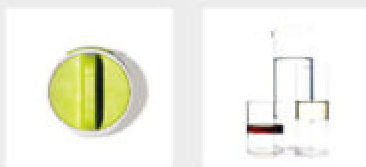
Join the discussion **#RWGibson**

Limited Edition - ***nabucco***







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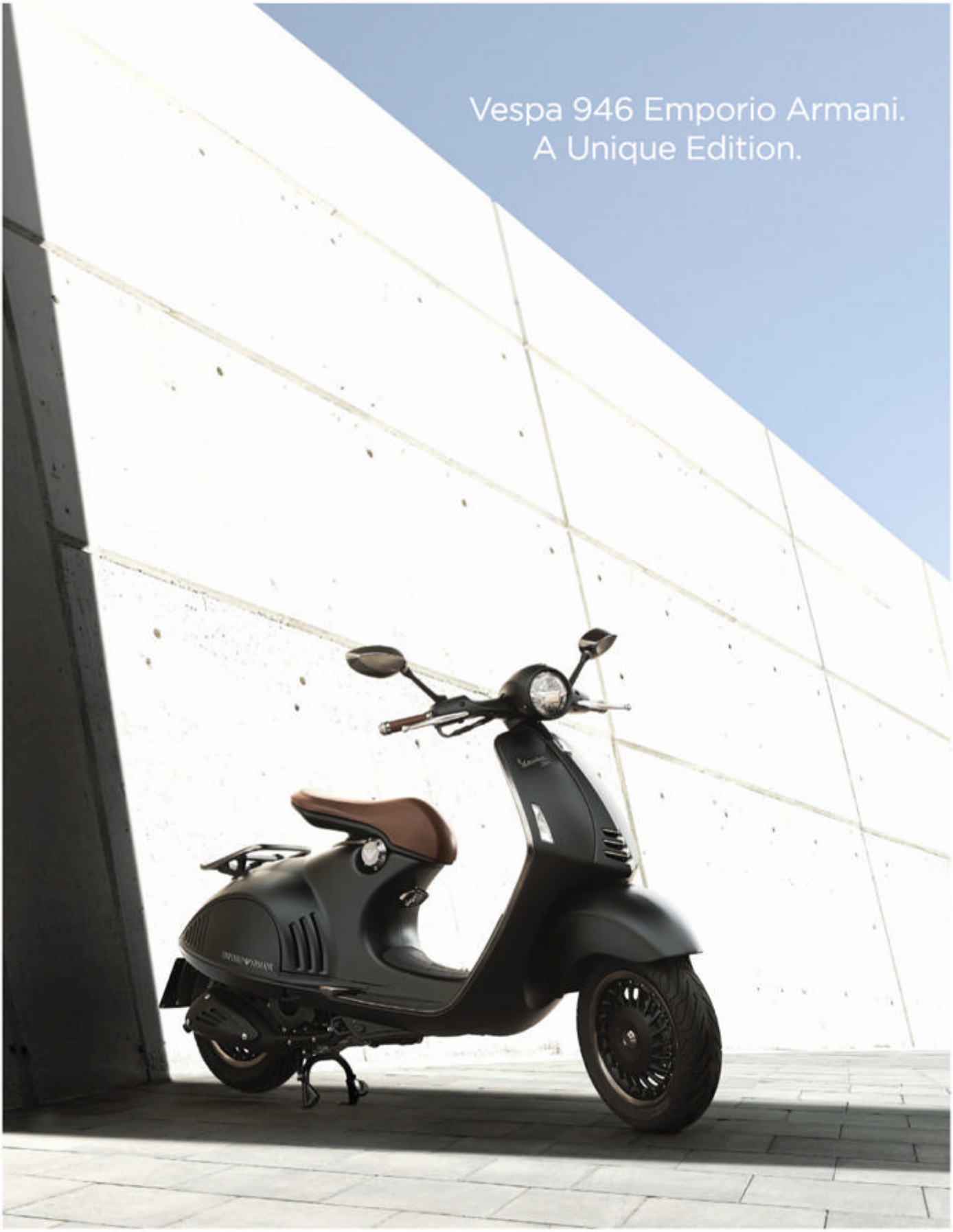

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Below:
Kathryn Fleming's bio-inspired Superbivore

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WIRED LOGO: KYLE WILKINSON. MADE BY SHOOTING HIGH-FALLING WATER ON TO A SUBMERGED LOGO AT 84MM, F/22 AT 1/80 SEC, WITH TWO DIRECTION SOFT BOXES AND THREE REFLECTED BULBS


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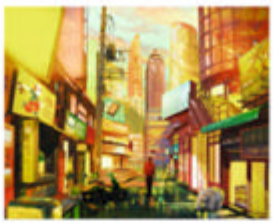
Shan Jiang illustrates our feature on Moore's law and the ad hoc future of tech development: "Although I haven't been to the Shenzhen electronics markets, I used to hang out in very similar places when I was at school in Shanghai during the 90s. I would go around these amazing stalls looking for parts for my PC – they're where I heard Moore's law mentioned for the first time. The illustration is based on my memories of those places, mixed with visual references to the real Shenzhen."



MAKING WIRED / IMAGINING SHENZHEN

MAKING WIRED / POWER SHOTS

WIRED sent photographer David Ryle to the Drax power station in Yorkshire for our feature on cybersecurity firm Darktrace: "I wanted to convey the enormity of it – Drax is on such a grand scale. It's both ugly and beautiful – albeit in an odd way. Whether real or perceived, you have to take threats to places like this seriously."

GREG WHITE

White visits McLaren this month– but not to photograph its race cars. Instead, he captured the team's work in streamlining other, less glamorous sectors – such as toothpaste factories. "The facilities were clean and minimal – a photographer's dream," he says. "F1 is all about timing, and every industry wants help with that."

JENNIFER JACQUET

The author of *Is Shame Necessary?* writes in Ideas Bank that, when used properly, naming and shaming can be a positive force. "Social disapproval might be wielded in considerate ways," she says. "For example, some non-profit groups have been calling out the worst banks funding mountaintop-removal coal mining."

ROBIN CHASE

Co-founder of Zipcar and Veniam, Chase posits that the internet has given us the tools to organise our way out of any problem through mass collaboration. "Access to the internet has permeated and impacted our business models," she says. "We are witnessing the rise of a new organisational paradigm I call Peers Inc."

STEPHEN LENTHALL

Hackney-based Lenthall contributes to our Gear we love list, photographing many of the items. "Everything in WIRED has a little bit of the future in it," he says. "The coloured steel trays by HAY are my favourite things. Next year's list needs to include cutlery by David Mellor – made in my native Derbyshire."

VLADAN JOLER

For Infoporn, the director of the Share Foundation reveals how much personal data your smartphone apps are leaking. "The idea was to create an internet privacy atlas – a visualisation of the hidden beneficiaries of your private information," he says. "Personally, I am a data and tech vegan. I practise a very strict diet."

PHOTOGRAPHY: DAVE LIDWELL; JASON MADARA; MACIEK JASIK; DAVID RYLE

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MAGAZINE

Generation gap

"I don't agree that online porn and gaming is the negative thing Philip Zimbardo makes it out to be (Arousal addicts, 06.15). Culture changes over time, and older generations are almost always horrified by what the kids are up to. And it does need to be said in this day and age, that porn and video games are for females too. If the future points towards more people doing it, then it's the sensibilities shocked by the prospect that will have to change." **Timothy Onion Moore, via Facebook**

"This is a massive generalisation. How does Philip Zimbardo justify making such broad-sweeping normative statements? Is anything this guy says supported by contemporary psychological science? I went to school at Stanford, and this is embarrassing." **david_l_laws, via *Instagram***

"Reading about Estonia's digital backbone in @WiredUK has blown my mind. It could literally restore from a backup or be run from the Caribbean." **@hunterruthven**

"So, in Murderous measurements (Infoporn 07.15), how exactly did Robert (Rob to his friends) Muggah end up working for a think tank specialising in security and crime issues - nominative determinism at work?" **Jamie Fraser, via email**

"This is the unfortunate thing that happens when millennials start running space programs." **@boringfileclerk, on "Thor", "Ariel" and "Xipe" being the names of potential future space projects**

"We'll know there are enough #womenintech when @WiredUK ads are for make up, not just aftershave." **@ViviFriedgut**

"One thing immediately strikes me whilst reading @WiredUK about #Google #DeepMind – without immigration and genius we wouldn't have it." **@SimonMoores**

"Nice one to @Google DeepMind featured in this month's @WiredUK – an example of UK business and tech on the global cutting edge. And great guys." **@michaelbhaskar**

"Know what's better than Musk debunking #AI? Demis Hassabis debunking Musk, Hawking, Wozniak on risks of AI." **@pedrobrazoul**

MAGAZINE

The AI feedback loop

"IT'S GOOD, BUT IT'S NOT MATTE!"

@WFazackerley (on the 07.15 cover)

MAGAZINE

Bitcoin matters

"Bitcoin lacks something all good currencies have – stability (Why the blockchain matters, 06.15). People want to know that prices in the shops are pretty much the same from one week to the next. This limits its use. A successful cryptocurrency needs stability mechanisms." **Tom Foale, via wired.co.uk**

"I wonder if Bitcoin is past the point where a group of governments could shut it down?" **Ron Sonntag, via wired.co.uk**

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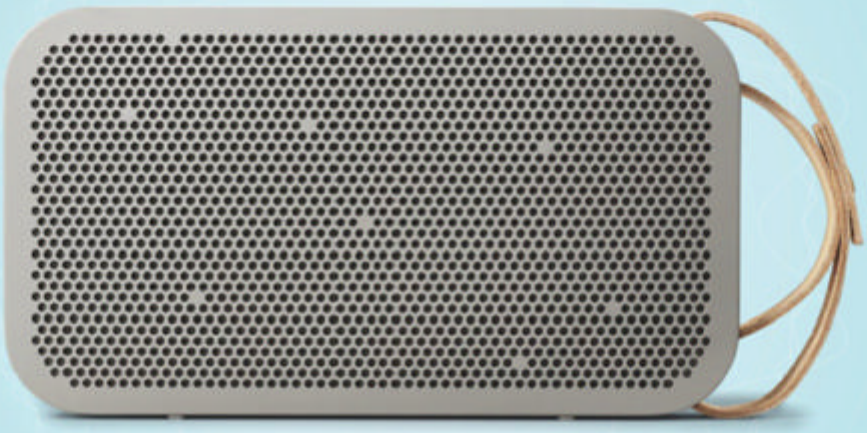

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FROM THE EDITOR

We've given you some pretty tough assignments lately as WIRED readers – from grappling with the ethics of artificial intelligence to hearing the traumatic stories of North Korean dissidents. So we decided to ease up on your homework this issue and mark the summer with a celebration of the products the WIRED team simply loves. With the assistance of action hero Simon Pegg, product editor Jeremy White has collected together 78 of our favourite ways to cook, relax, travel, work, create – and of course to snoop from above.

What makes something "WIRED"? Our team tends to look for a seamlessness of design, a boldly fresh implementation, a reinvention of something we never realised needed fixing. But mostly we follow our gut: when the Tentsile Stingray Tent makes us yearn to go camping, the Silent Circle Blackphone 2 makes us want to play spy, or Product Hunt keeps us longer at our screen than we'd planned. We don't have a WIRED awards ceremony, but if we did, these are the life-enhancers we'd garland with trophies (made out of graphene, or grown in a bio lab). To all the creators of smartwatches, addictive transportation apps and electric cars – we salute you.

We had a discussion at a recent WIRED round-table dinner about Moore's law – and for how much longer it will stand. The consensus among some very smart people was that the limits are near. This month we asked Andrew "bunnie" Huang, a celebrated hardware hacker and thoughtful tech commentator, to visit the markets of Shenzhen to tell us what will happen next. Huang sees the implications already hitting hardware – as phone computing progress slows down, he argues, market advantage will come from the ability to personalise devices, which will be in more modular form. What really stands out in his report is the democratisation of hardware that's happening now – as high-end smartphone parts get commodified, soon it seems all of us will be better able to design our own devices.

We're about to host our third WIRED Money event in London, with more than 20 speakers from firms such as Adyen and TransferWise. Deputy editor Greg Williams, who programmes the day, has seen the sector mature in the three years we've been running the event – and London still seems to be the home of finance-tech innovation. "What's extraordinary is the accelerating pace of change," Williams says. "There are an increasing number of fintech startups that are experiencing impressive growth and solving problems in both the consumer and B2B space. We'll be showcasing some of the thinkers behind these businesses and looking towards the future of the sector with a particularly exciting series of keynotes on how the blockchain may have a comparable, transformative effect to the internet itself." If you can't be there, follow the talks at wired.co.uk.

Our well-kitted-out cover star is shaken – but not stirred

PHOTOGRAPHY: GARY SALTER

DMA MAGAZINE OF THE YEAR 2014 • DMA TECHNOLOGY MAGAZINE OF THE YEAR 2014 • BSME ART DIRECTOR OF THE YEAR, CONSUMER 2013 • PPA MEDIA BRAND OF THE YEAR, CONSUMER 2013 • DMA TECHNOLOGY MAGAZINE OF THE YEAR 2012 • DMA EDITOR OF THE YEAR 2012 • BSME EDITOR OF THE YEAR, SPECIAL INTEREST 2012 • D&AD AWARD: COVERS 2012 • DMA EDITOR OF THE YEAR 2011 • DMA MAGAZINE OF THE YEAR 2011 • DMA TECHNOLOGY MAGAZINE OF THE YEAR 2011 • BSME ART DIRECTOR OF THE YEAR, CONSUMER 2011 • D&AD AWARD: ENTIRE MAGAZINE 2011 • D&AD AWARD: COVERS 2010 • MAGGIES TECHNOLOGY COVER 2010 • PPA DESIGNER OF THE YEAR, CONSUMER 2010 • BSME LAUNCH OF THE YEAR 2009

David Rowan

Salt lake pretty

This is not a watercolour. It's the 7,000-hectare Shark Bay salt field in Useless Loop in western Australia. What look like brushstrokes are the marks left by salt-harvesting machines, which produce about 1.6 million tonnes of the purest-grade salt in the world every year. "The salt is extracted from very pure high-saline seawater, 50 per cent more saline than the ocean," says Graeme Landgren, general manager of the plant, which is owned by Japanese corporation Mitsui Group.

Salt water is pulled into closed lagoons by wind, gravity, a few pumps and the tide. Then evaporation and wind gradually concentrate it. After it is pumped into shallow crystallising ponds, further evaporation leaves a thick layer of very pure salt. When 20cm to 40cm of it remains, it's harvested and accounts for 93 per cent of Australia's salt production.

"Salt from Useless Loop is among the highest natural-grade solar-marine salt found anywhere in the world," says Landgren. And the area is just as exclusive. Though surrounded by Shark Bay, a Unesco heritage site, no tourists are allowed. Instead, only the salt fields' employees and their families live in the area. "We have our own private town," says Landgren. Salt: still shaking things up.

Sophia Epstein

www.salt.com.au

The refined salt is exported to Japan, Taiwan, Indonesia and the Philippines

PHOTOGRAPHY: SIMON BUTTERWORTH

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Ryan Hoover, founder of San Francisco-based Product Hunt

HOW THE PROPHET OF PRODUCTS HELPS STARTUPS TAKE OFF

Ryan Hoover's Product Hunt is fast becoming the newswire of cool launches

RYAN HOOVER TOOK FIVE DAYS TO build his website, Product Hunt. Launched in December 2013, Hoover's site started off as a daily email newsletter for enthusiasts to gush about the coolest new things – from music apps to productivity tools, smart kitchenware and games.

Now the site has become a Reddit for tech. Fourteen thousand listed products are ranked by an expert community, and 140,000 subscribe to its daily email. Visitor numbers are growing 50 per cent month on month, and Hoover has raised $7m (£4.5m) from investors including Andreessen Horowitz, Google Ventures and Y Combinator. "We are driving more than 2.5 million monthly visits from Product Hunt to the websites of products we feature," says Hoover.

On the *Product Hunt* iOS app, you can follow users, curate collections, discover recommendations for related products and search. The target communities are journalists, investors and makers. "It's a place where founders are unedited – they use the comments to explain their product features or give and take feedback very honestly," Hoover, 26, says. "In April 2014, a European video communication app called *Taptalk* was spotted by a Silicon Valley angel investor who saw it on Product Hunt, became an early user, and ended up investing in them. That led to other investors coming in as well." Hoover says that live video-streaming app *Meerkat* also credits Product Hunt as its media launchpad.

His plan for this year is to expand beyond tech products to music, entertainment and books. To this end, he recently launched Snoop Dogg's new album *Bush* through the site, which he says received 2,600 clickthroughs to Google Play within five hours of going live. And he's definitely thinking about making money. "The obvious short-term options are product promotions. We record every time people click or up-vote a product, so we can use the data to know exactly what people like," he says. "We want to help people make transactions quickly, so it's easier for them to buy products through the site." **MV** *producthunt.com*

TECH TOP-FIVE: PRODUCT HUNT'S MOST UP-VOTED INNOVATIONS

- **Startup Stash** *Business resources*
- **Periscope** *Point-of-view films*
- ***Product Hunt* for iOS** *Recommendations*
- **Tesla Powerwall** *Home battery*
- **Be My Eyes** *Assisting the blind*

PHOTOGRAPHY: GABRIELA HASBUN

Design your own drugs

For truly personalised medicine, plug in Martin Burke's molecular 3D printer and create a treatment

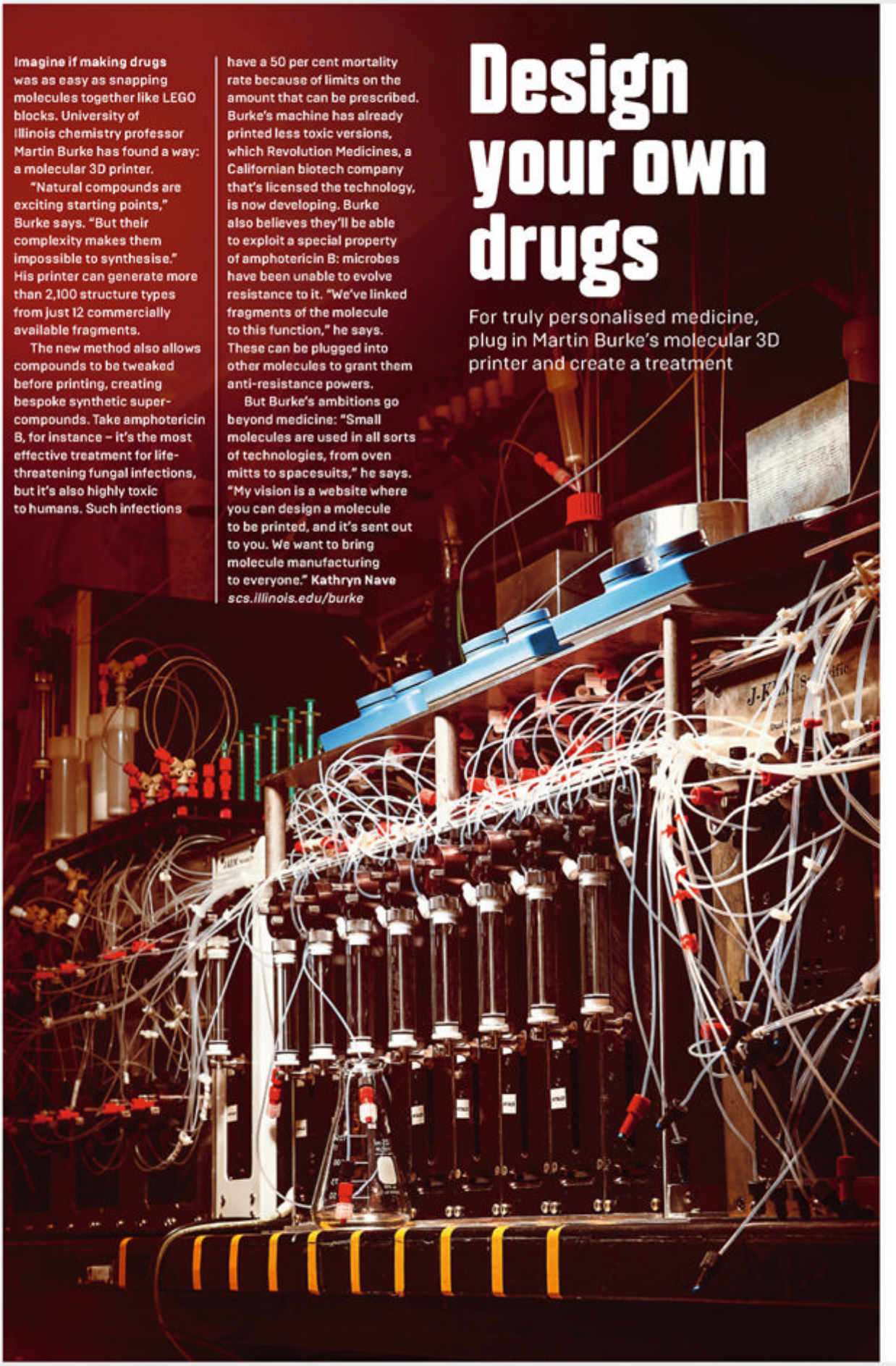
Imagine if making drugs was as easy as snapping molecules together like LEGO blocks. University of Illinois chemistry professor Martin Burke has found a way: a molecular 3D printer.

"Natural compounds are exciting starting points," Burke says. "But their complexity makes them impossible to synthesise." His printer can generate more than 2,100 structure types from just 12 commercially available fragments.

The new method also allows compounds to be tweaked before printing, creating bespoke synthetic super-compounds. Take amphotericin B, for instance – it's the most effective treatment for life-threatening fungal infections, but it's also highly toxic to humans. Such infections have a 50 per cent mortality rate because of limits on the amount that can be prescribed. Burke's machine has already printed less toxic versions, which Revolution Medicines, a Californian biotech company that's licensed the technology, is now developing. Burke also believes they'll be able to exploit a special property of amphotericin B: microbes have been unable to evolve resistance to it. "We've linked fragments of the molecule to this function," he says. These can be plugged into other molecules to grant them anti-resistance powers.

But Burke's ambitions go beyond medicine: "Small molecules are used in all sorts of technologies, from oven mitts to spacesuits," he says. "My vision is a website where you can design a molecule to be printed, and it's sent out to you. We want to bring molecule manufacturing to everyone." **Kathryn Nave**

scs.illinois.edu/burke



PHOTOGRAPHY: L BRIAN STAUFFER

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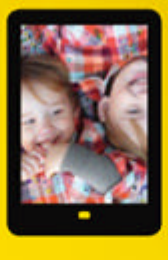

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You too can be an app

Alexia McKenzie wanted to optimise her life – so she inserted a magnet under her skin

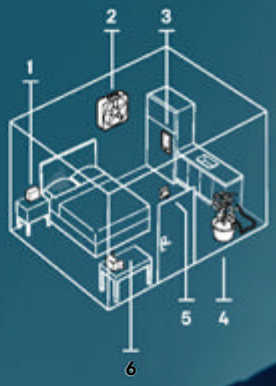
HARDWARE DESIGNER Alexia McKenzie is surrounded by chronic time-wasters. They check their mail when they return home. (Typical.) They answer their front door when someone knocks. (Lame!) They even do their own laundry. (Why?) McKenzie doesn't want any of this.

If there's a way to eliminate an inefficiency, McKenzie will find it. She installed a sensor that tells her when a letter arrives. A webcam live-streams a view of her doorstep to her phone, so she always knows who's knocking. As for laundry, she doesn't bother – don't you know there's an app for that? After years of testing and tinkering, McKenzie has transformed her life into a smooth operation managed by apps and hardware. She Lyfts to work, keeps a tablet open to *Instacart* on her fridge (she never runs out of eggs), and waters her plants remotely. Rigging all this stuff can get complicated, though, so she's taken optimisation one step beyond: McKenzie had a tattoo artist implant a magnet under the skin of her left hand to hold metal parts as she works. "I'll be fiddling with a wire or a screw, and I'll be like, live there for a moment," she says, pointing to the spot. Then she shows off, using another magnet to make the one in her hand spin in circles: "I can make it dance!"

Now San Francisco-based McKenzie is helping others better streamline their lives. For example, her mum doesn't like getting out of the shower, so McKenzie made her a heated bath-mat to ease the transition. And when people invaded a local community centre, she set up an electronic lock system and distributed keycards to the other members. Of course, McKenzie doesn't need one herself, as she has a radio tag embedded next to her magnet – the key is always in her hand. **Mallory Pickett**

HOW MCKENZIE HAS AUTOMATED HER LIFE

1. A DIY "brainbox" emits soundwaves to help her sleep
2. Her room fan switches on at a set temperature
3. *Instacart* stays permanently open on her fridge
4. A homemade irrigation system waters her plants
5. A webcam tells her who's at the front door
6. A sensor pings her when a letter arrives

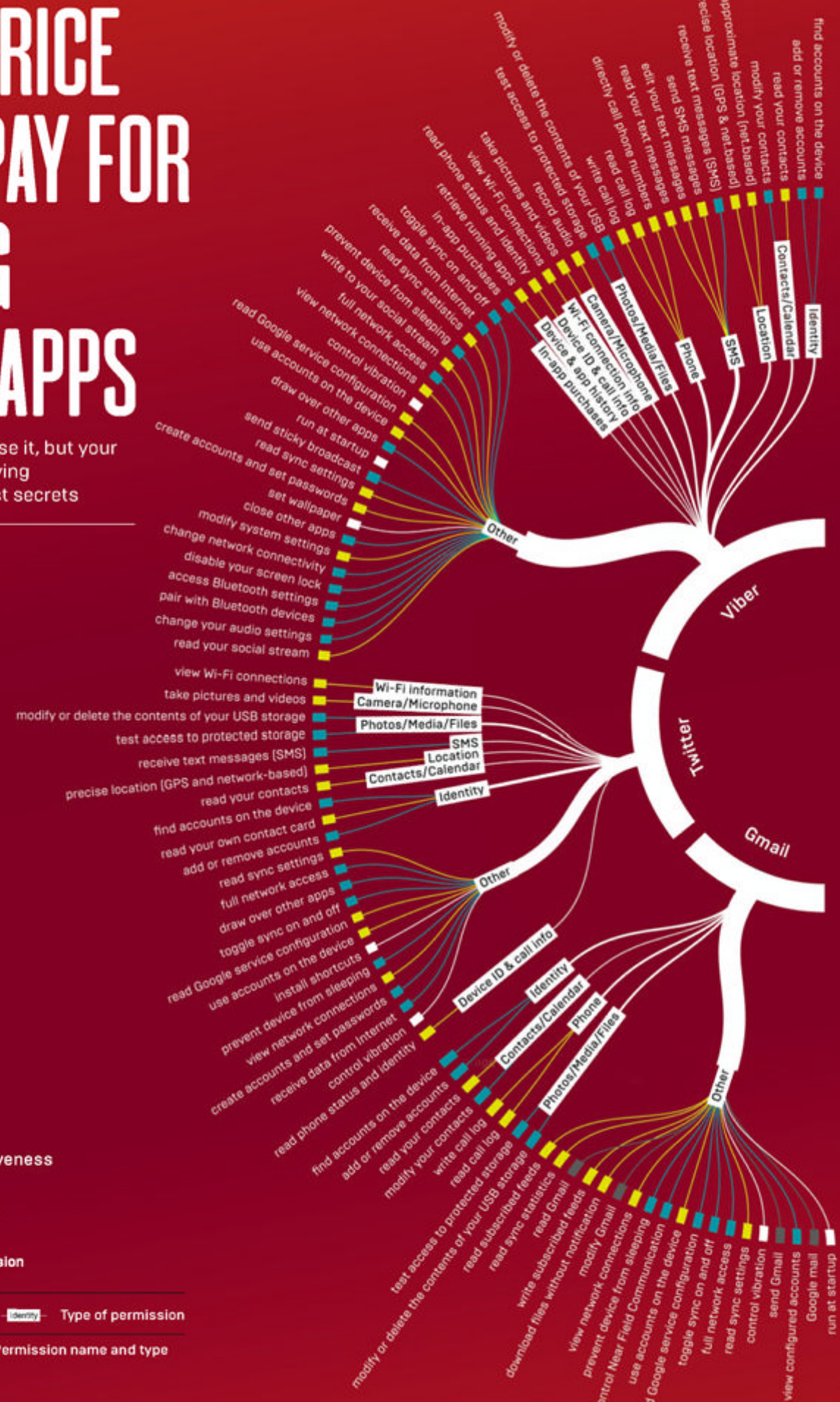


Hands free: Alexia McKenzie with a speaker attached to her magnet

PHOTOGRAPHY: IAN ALLAN. ILLUSTRATION: JASON LEE

THE PRICE YOU PAY FOR USING FREE APPS

You may not realise it, but your smartphone is giving away your deepest secrets

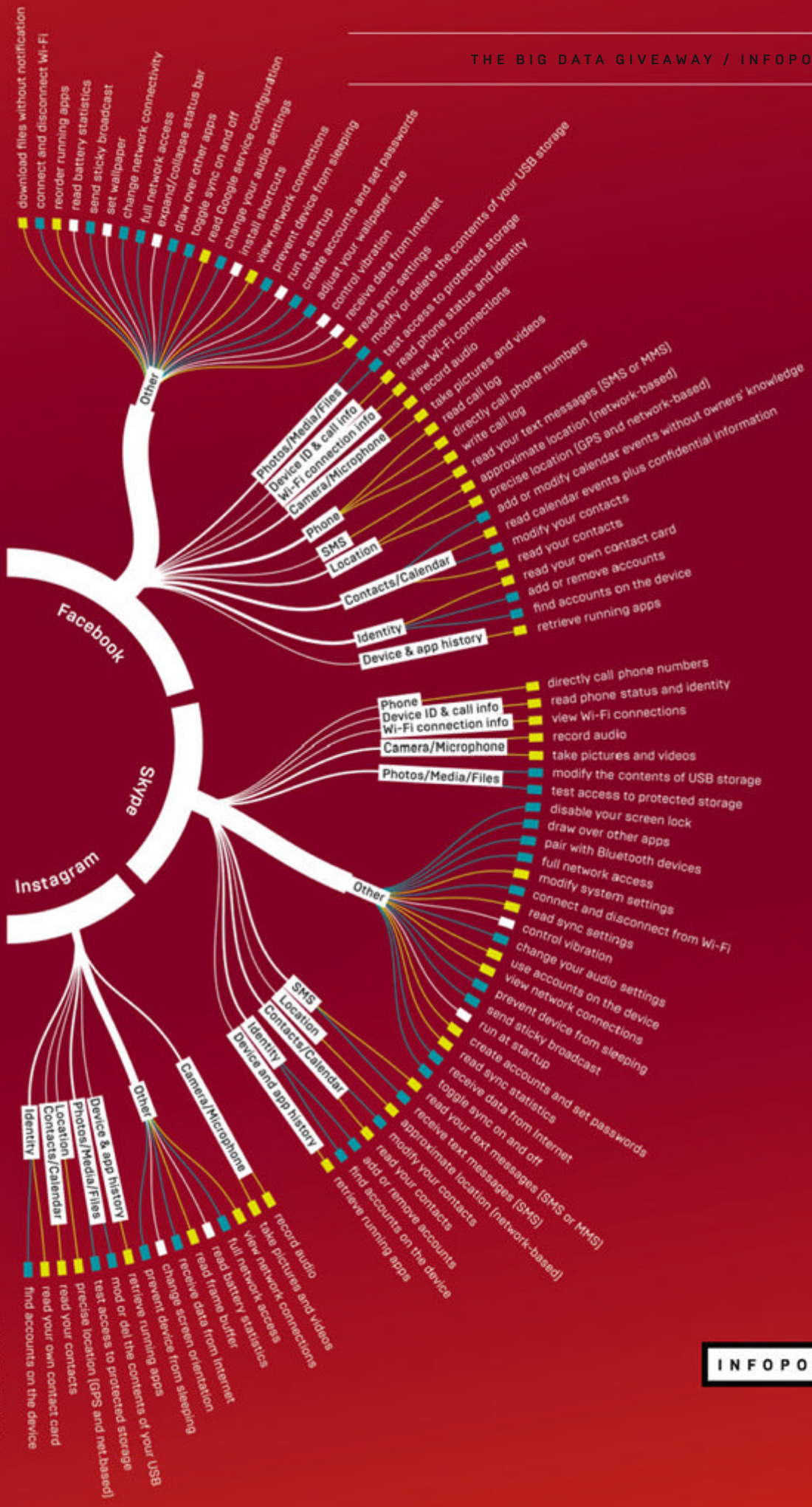


Permission intrusiveness

- High privacy risk
- Medium privacy risk
- Low privacy risk
- App specific permission

Application — Type of permission

read call log — Permission name and type



INFOGRAPHIC: VLADAN JOLER

You are looking at a map of all the permissions you have given six popular smartphone apps – Facebook, Twitter, Gmail, *Instagram*, Skype and *Viber*. *Instagram* can use your camera and microphone to record audio and take pictures and video, without asking you first. Gmail can read and modify your phone contacts. *Viber* has your precise GPS location at all times. Facebook can read all your text messages. "These are permissions that the apps require you to grant them before they are installed," says Vladan Joler, the data wrangler behind the visualisation and director of the Serbian non-profit SHARE Foundation, which campaigns for internet freedoms. "The purpose of this visual is to show, in a clear way, what smartphone users agree to when they click 'yes' on terms and conditions."

Read the map from the centre outwards: starting with the application itself, examine the list of permissions each requires, followed by what these permissions really imply, ranked by how intrusive they are. "Even with just these six apps, you are giving away pretty much all the metadata that exists on your phone," Joler says. "They have permission to access sensitive information such as who you called, when you called them and how long the call lasted."

His goal is to remind you that every free app makes money by collecting your personal data and creating a profile of you that can be monetised and sold on to third parties. "Mobile phones have hugely expanded the intimacy and quality of the information they gather," says Joler.

MV *labs.rs/en*

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Which country should this Israeli live in?

Um, France... but let's not get distracted by Shaul Olmert's quizzes, which made PlayBuzz Facebook's most viral app

WHICH COUNTRY BEST SUITS YOUR personality? Shaul Olmert knows. PlayBuzz, the 40-year-old Israeli's startup, is conquering Facebook with shareable quizzes such as "What is Your Spirit Emoji?" But its real lesson is the exponential power of virality.

"In our first month we had 3,000 users," says Olmert. "In our second, 13,000. Third, three million. Fifth, 20 million." In January 2015, just over 12 months after its official launch, PlayBuzz overtook BuzzFeed and the Huffington Post to become the most-shared content source on Facebook, according to analytics firm NewsWhip.

The son of convicted former Israeli prime minister Ehud Olmert – currently appealing a six-year jail sentence for bribery – Olmert worked for MTV/Nickelodeon before launching a series of troubled startups. He founded PlayBuzz in July 2012 as a platform to let anyone create BuzzFeed-like listicles. Olmert soon embraced growth hacking (WIRED 09.14) – testing and iterating the design to increase shareability. "People ask us: how did you reverse engineer the Facebook News Feed algorithm?" he says. "The truth is we have no idea how it works. But we asked ourselves: what is Facebook trying to encourage? The answer is simple: mindful sharing."

"The quiz is a very personal format," says PlayBuzz chief content officer Shachar Orren. "It creates a feeling of 'this is about me', and you're more likely to share it." Twenty thousand creators now post on PlayBuzz, along with high-profile brands. "We work with AOL, Fox, the *Mirror*, the *Daily Telegraph*, Sky..." says Olmert. "Many of them create amazing content. Some create mediocre content." PlayBuzz's ambition isn't to be a BuzzFeed clone, Olmert says, but a platform for content creators. "We always say that if content is king, the platform is the palace."

PHOTOGRAPHY: JORDAN HOLLENDER

So what happens when Facebook inevitably alters its News Feed algorithm? "I tend not to live my life based on some disaster scenario," says Olmert. He points to his app's growth on Pinterest, Twitter and other social media, and an in-house team is also focused on developing new formats. Whatever form it takes, he says, "we'll be there to democratise it." And in case you're still wondering, Olmert should move to France. **OF-W** *playbuzz.com*

PLAYED BY OLMERT AND SEVEN MILLION OTHERS

The "What Country in the World Best Suits Your Personality?" quiz was created by PlayBuzz member Lara Kosheez. Questions include "Which drink would you prefer?" – choose from a Mai Tai, wine or whiskey.

ILLUSTRATION: JASON LEE

VOLVO'S LOUNGE ACT

To cater to the ultra-high-end market, the Swedish car company made an unexpected move: it deleted some seats

Riding shotgun has been a fine automotive tradition since the turn of the 20th century. Like the stagecoach before it, nearly every car produced has had two front seats – or at least space for two.

Now an unlikely maverick, Volvo, is deleting that passenger perch. The target for this shotgunless horseless carriage: China, where the luxury sector is booming and chauffeurs are now standard equipment. Such thinking is making the back seat the place to be.

Of course, plushing out the rear seats is common these days, so Volvo built the Lounge Console Concept SUV. Based on its roomy XC90, this modern-day palanquin ditches not only the production model's third row, but also the front passenger's spot. Spanning that newly open space is a reclining seat, hectares of legroom and an ottoman-TV-work-table–storage-unit mashup. Evidently it's not enough to be driven around by a minion; you also want to put your stinky feet right next to them.

At first glance it seems absurd to remove the front seat, but for those folks with *Downton Abbey*-scale aspirations, it actually makes some sense. Volvo might never put the Lounge Console into production, but for now the XC90 Excellence edition, with no third row, four seats and tonnes of rear legroom, will be available to titans of industry later this year. Just holler at Jeeves to go once more round the park while you sit in the back row, right-swiping *Tinder* while pretending to catch up with your business affairs.

Jordan Golson

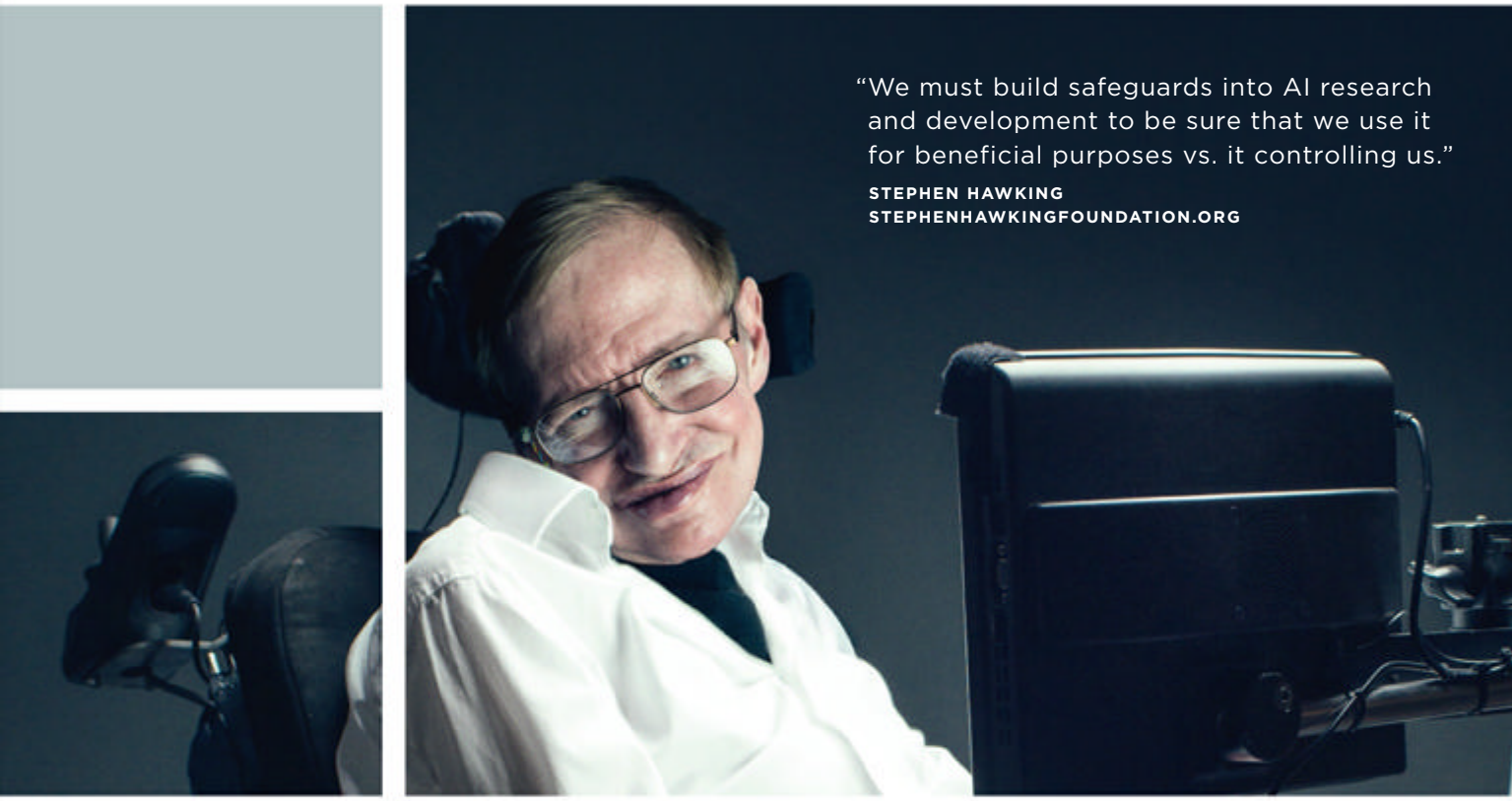
1

2

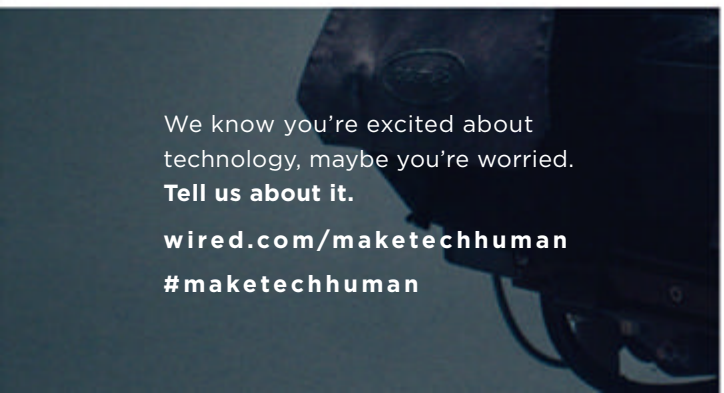
1. Volvo's Lounge Console ditches the passenger seat for an articulating desk/screen.
2. Your mobile throne room includes a 17-inch TV, plush leg rest and a niche for your rival-stomping shoes.

MAKETECHHUMAN

THERE'S NO TIME LIKE THE PRESENT TO SHAPE THE FUTURE.



NOKIA AND WIRED took the #maketechhuman conversation to iconic theoretical physicist Stephen Hawking. While advancements in artificial intelligence are poised to solve some of humankind's most difficult problems, Hawking cautions that the technology could spell the end of the human race if left unchecked. Hawking is an early adopter of communications technology—a primitive form of AI—but he fears the consequences of machines that will "supersede" humans. Along with tech luminaries Elon Musk and Bill Gates, Hawking signed an open letter earlier this year imploring researchers to balance the benefits of AI with the risks. The letter acknowledges that AI might one day help eradicate disease and poverty, but it also puts the onus on scientists at the forefront of this technology to keep the human factor front and center of their innovations.



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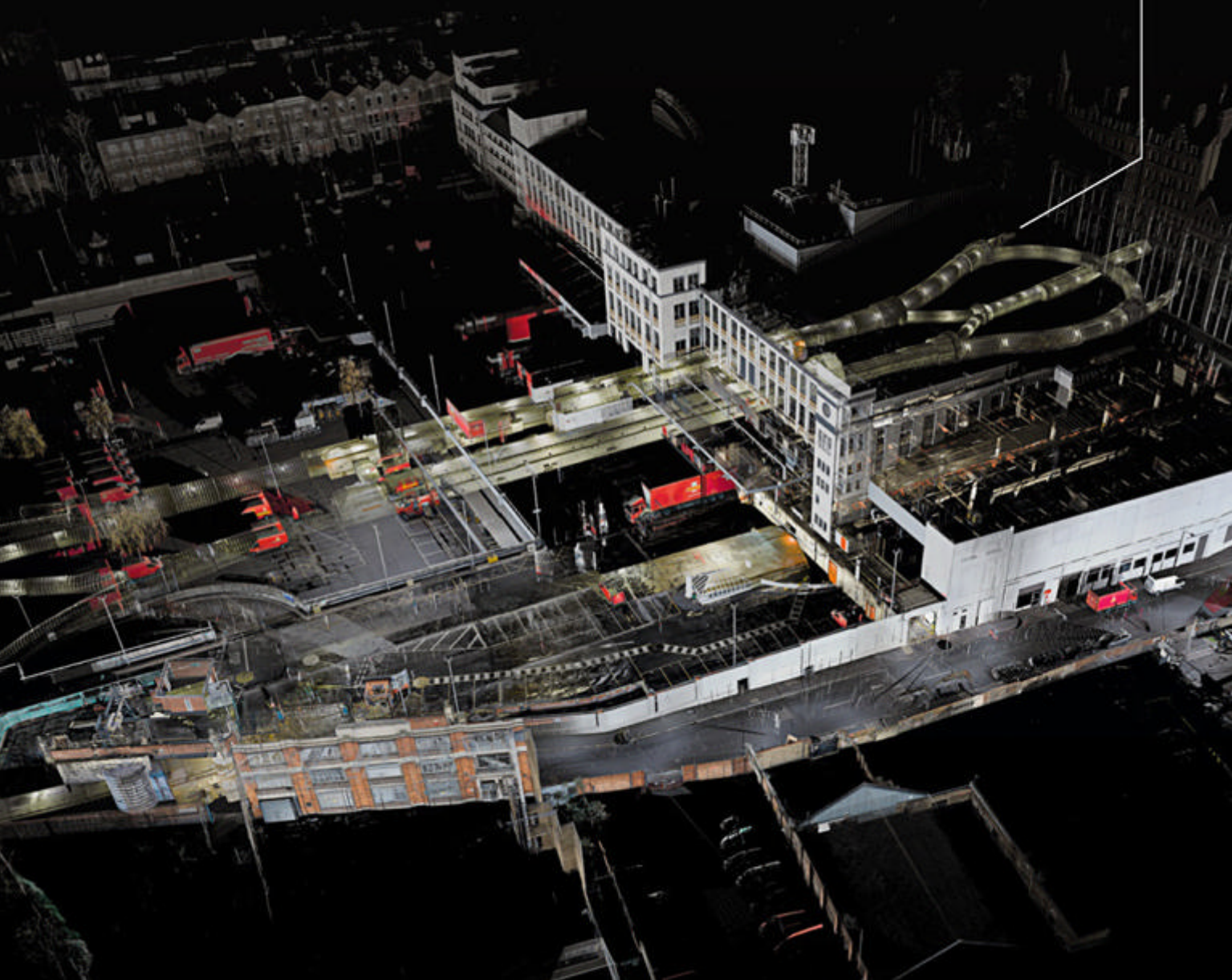
HOW SCANNING LET THE MAIL RAIL PREVAIL

SUBTERRANEAN LONDON'S POST OFFICE RAILWAY – THE HISTORIC Mail Rail – is about to be torn down and transformed into a tourist attraction. "The air has been so still down there that stalactites have formed," says Martin Devereux, head of digital at the British Postal Museum and Archive, about his eerie visits to the long-forgotten Mail Rail. Now the facility has been scanned in 3D and preserved for posterity. Last December, a team from London 3D-scanning firm ScanLAB was let loose with a FARO Focus3D 120 laser scanner which can create high-resolution, 3D scans of complex interior spaces. The process took five days. "They've given us something really rather beautiful," Devereux comments.

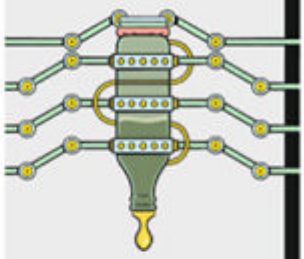
The underground-railway system delivered post between sorting offices in London from 1927 until it was decommissioned in 2003. Now, the tunnels are to be redeveloped and opened to everyone, with attractions such as a Mail Rail ride. Before that can happen, extensive renovations will take place. "It's an industrial space," says Devereux. "It's not set up for the public, so it's going to be changed. We'll be putting in things like fire escapes, for example. We'll have to take some of the old structures away." Now that the scans have been made, however, Devereux hopes that they will be used to create a virtual, interactive replica of the original tracks. "We could take somebody, put an Oculus Rift on them and put them in Mail Rail in their own bedrooms." **Chris Baraniuk** *postalheritage.org.uk*



The tunnels run under the Mount Pleasant Mail Centre in Clerkenwell in central London

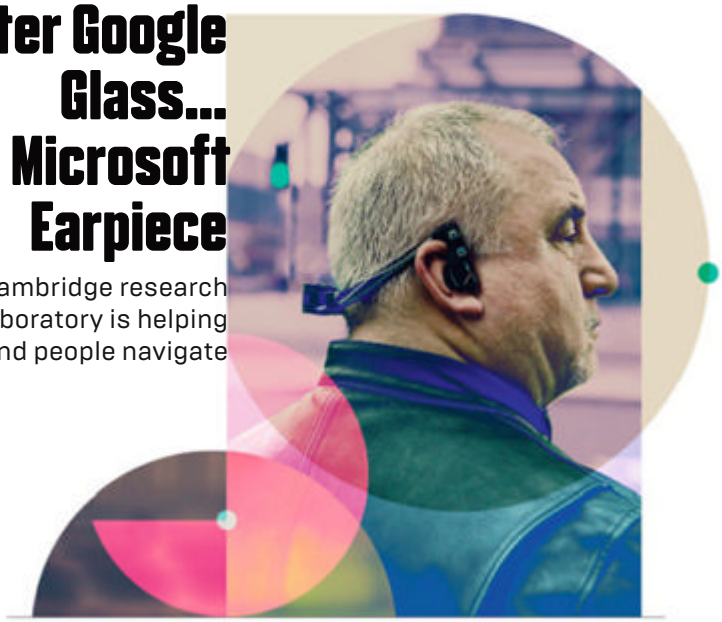
A total of 223 laser scans, making 11 billion datapoints, were completed for the Mail Rail site

PHOTOGRAPHY: DAVID VINTINER. ILLUSTRATION: GIACOMO GAMBINERI



After Google Glass... it's Microsoft Earpiece

A Cambridge research laboratory is helping blind people navigate



This headset could replace guide dogs for the visually impaired. Developed by Microsoft and UK charity Guide Dogs, the vibro-tactile device prototype is equal parts satnav, seeing-eye dog, and tour guide. It tethers to a phone's GPS and Bluetooth connection to create a three-dimensional soundscape of the surroundings. Wrapping around the back of your head, it rests atop your jawbone, sending vibrations via conduction into the user's skull (*as worn above by early adopter Dave Kent*).

"It doesn't sit in your ear like headphones because that would block out ambient sound," says Natasa Milic-Frayling, a principal researcher at Microsoft Research Cambridge, who was part of the development team along with engineer Steve Hodges and Angus Foreman, chief technology officer of Microsoft Services. A patter of footsteps straight ahead leads the way; higher-pitched pinging moves around you in three dimensions to let you know whether you're wandering off in the wrong direction.

Embedded in the back of the headband are three sensors: an accelerometer, a gyroscope and a magnetometer, together forming a digital compass. "These three sensors all combine so that, as you rotate your head, we send a Bluetooth signal to the phone, which shows how your head is changing direction," explains Hodges. The headset recalculates the wearer's position up to 100 times per minute, and the phone spits back audio that seems to be coming from above or below, left or right, near or far. The invention isn't just about positioning you on the pavement. "One of our ambitions is to allow partially sighted people to be more spontaneous," says Foreman. A built-in Bluetooth beacon tells wearers when they pass major landmarks – from whichever direction the landmark is, based on their location. Wear the headset on a bus and it'll tell you when your stop is close.

Initial trials by partially sighted people showed improvement for test subjects on ten of 17 measures, including confidence on the streets. But before the invention can have widespread usage, mainstream technology has to catch up – and it could take years to do so. GPS coverage isn't yet stable enough for the headset to work everywhere. Next step – reinventing GPS?

Chris Stokel-Walker

research.microsoft.com

Beer-improvement researcher

Aberystwyth University is offering a PhD in how to make a finer pint. Successful applicants will be enrolled in the "Happy yeast makes better beer" programme, where they will be determining the "impact of brewery-related stresses on yeast" in order to make it perform better and produce a more flavoursome ale. At last, a PhD that encourages having a beer at the end of the day, or throughout it.

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Biomimicry builder

Melissa Sterry uses nature to help victims of extreme weather

ELISSA STERRY WANTS TO BUILD TOUGHER environments. The London-based design scientist and futurist believes that if urban architecture mimics nature, it could be more resilient to droughts, heatwaves and floods. It's an ideal she calls the Bionic City. "I was asking the question, how would nature build a city?" says Sterry, 42. Using her knowledge of biomimicry, she advises NGOs and designers on how to incorporate biodiversity and support natural systems that make cities more adaptive to change.

One of Sterry's recent projects took her to the Philippines, in the wake of Typhoon Haiyan. The superstorm had destroyed tonnes of vegetation, but she noticed that resilient species such as bamboo quickly regrew. Taking these ecological cues as inspiration, Sterry and Filipino-American architect Lira Luis developed the Living Ball, a building that can temporarily house displaced families. The four-person structure comprises locally abundant bamboo that makes up its flexible, weather-resistant frame. It can be air-dropped into disaster zones and the design is open source so anyone can build it.

Next up, Sterry (*pictured right with a Living Ball*) is exploring how bioluminescent algae that flourish on local shores can be used to light up the Living Ball. This year, she plans to scale up the prototype to create larger community structures such as schools and civic centres. Steel and glass buildings are the enemy of structures like the Living Ball, says Sterry: "Ecologically, they're obnoxious," she says. "When we rebuild we should evolve the solution. We shouldn't just build things exactly as we did before." **Emma Bryce** *melissa-sterry.squarespace.com*

The Living Ball biodegrades after it's used

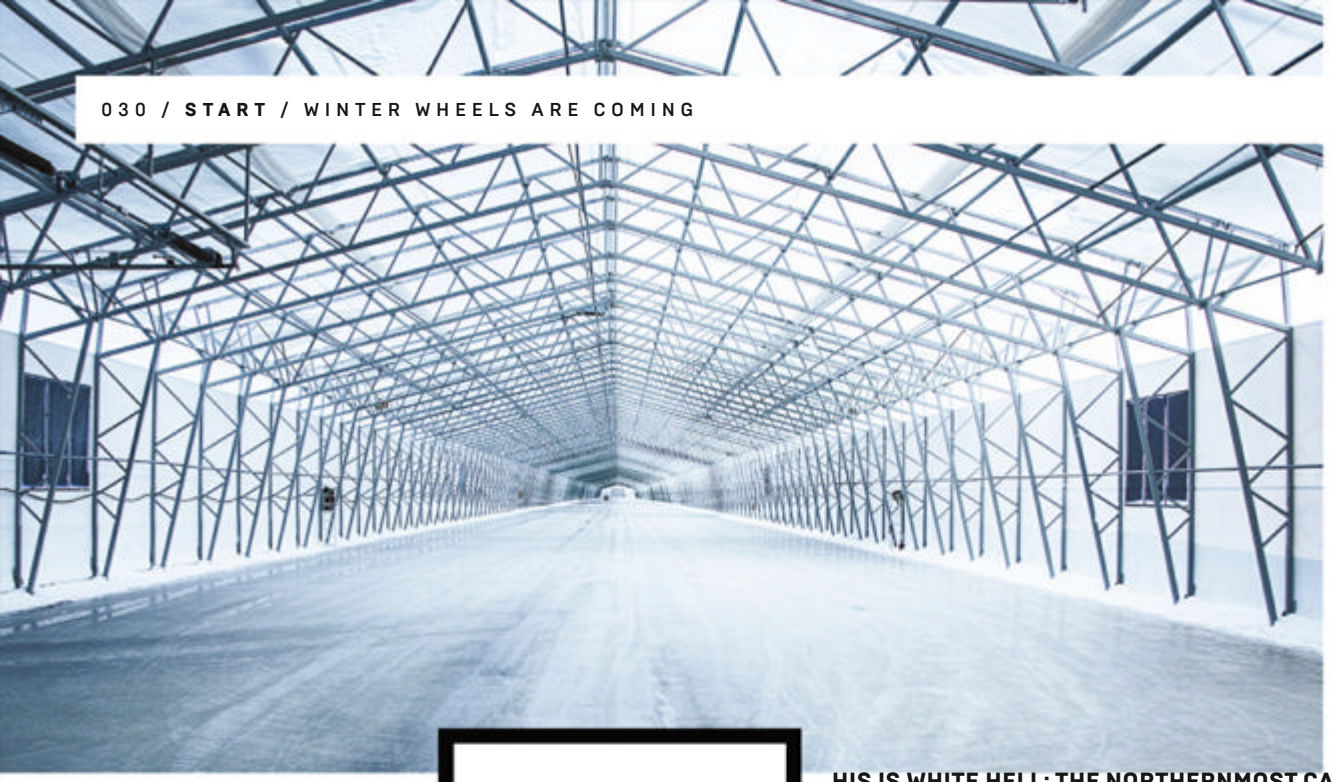
PHOTOGRAPHY: SHAMIL TANNA. ILLUSTRATION: JAMES POP

THINGS ARE LOOKING UP FOR AR

Skignz is using augmented reality to create signposts in the sky. Available on iOS and Android devices, the startup's app is the latest in a wave of "serious" AR products which companies such as Blippar are also working on. "Up to now, augmented reality has presented itself as an image search engine," says skignz co-founder Si Brown, 40. "We want to use geolocation to combine maps and search."

Skignz users can place a virtual pin on objects – pop one above your car, for instance, and it will help you find it when you're in the supermarket car park. Or you can drop a roving pin on a friend at a festival vto keep track of them via GPS.

The Stockton-on-Tees-based startup – the name is pronounced "skines" – has signed a deal with drinks company Diageo to set up a pilot project flagging up bars in busy locations and take customers to its website. The real-world search engine may have finally arrived. **Chris Stokel-Walker** *skignz.com*



A song of ice and tyres

Designing winter wheels? You'll need the world's most extreme testing centre

THIS IS WHITE HELL: THE NORTHERNMOST CAR-TYRE testing centre in the world. Spread over 700 hectares of Finnish Lapland, the facility boasts more than 20 testing sites, from snow-covered tracks to iced-over lakes – and more are added every year. The latest addition is an ice-filled indoor testing track over 600 metres long and 50 metres wide (*above*). "We can start testing earlier in the year now, compared to when we just had the normal ice courses," says Matti Morri, technical customer service manager for the centre. "We'd have to wait until the lakes had 10cm-thick ice before we could drive on them."

Known formally as the Ivalo Testing Center, it is mostly used by Finnish tyre-maker Nokian to test out its creations, between November and May. "When we start to develop a tyre, we have from four to six kinds of pattern, tread compounds and structures," says Morri. As the testing goes on, the weaker designs are cut, and the best features are kept. This means working six days a week with skilled drivers, he says. "Last season, we tested over 20,000 experimental tyres."

Each tyre design can take up to five years to be assessed, a process involving both summer and winter testing. The Arctic conditions are extreme, and temperatures can fluctuate up to 40˚C throughout the day, but this is essential. "You have to test and develop tyres in the same sorts of conditions that people use them," says Morri. Although computer simulations have greatly improved, they are not enough. "This kind of outdoor testing is the only way of building these types of tyres." **Sophia Epstein** *nokiantyres.com*

"White Hell" is located 300km north of the Arctic Circle

EARLY ADOPTERS

WHAT'S EXCITING...

DAN HILL

Chief design officer, Future Cities Catapult

"Justin McGuirk's book, ***Radical Cities***, covers the recent history of major Latin American cities, from Buenos Aires to Tijuana. The ideas here have been forged in challenging environments. As such, they feel like they might be profoundly generative anywhere."

WHAT'S EXCITING...

DESSI BELL

Founder/CEO, Zaggora and Bijoux Place

"I am beta testing ***Mailcloud***, which is a collaboration app built on your email. It lets you find documents without sifting through your messages for hours. ***Sessions*** is a great app that helps you form good habits. I believe that our life is guided by habitual behaviour."

WHAT'S EXCITING...

ROGER HARTLEY

Artistic director, Bureau of Silly Ideas

"The ***Beano iPrank*** app, with its 'Fart finder', is a favourite at the Bureau of Silly Ideas. In sensible use, ***Evernote*** is rocking along as an asset for collection of inspiration, running of projects and management of memory. I almost love it as much as chips." **SE**

PHOTOGRAPHY: VILLE HEINONEN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THE BIG QUESTION

WHAT WILL URBAN TRANSPORT LOOK LIKE IN TEN YEARS?

SONJA HEIKKILÄ

TRANSPORT ENGINEER,
ADVISER TO FINNISH FUNDING AGENCY FOR INNOVATION

"Transportation will shift from owning to using. We will be able to take a bus, a taxi, use a minivan or book a limousine service through a touchscreen. There will be less need for individuals to own a car, as transportation will become demand-responsive and adapt to the individual needs of people. Instead, conveyance will become a tool to be accessed, provided by third parties. The intrinsic value of owning a vehicle will diminish. Shared and rentable vehicles, as well as the broader transport system, will be automated, which will enable maximum efficiency in operation." **Sophia Epstein**

RICHARD DE CANI
DIRECTOR OF STRATEGY AND POLICY, TRANSPORT FOR LONDON

"London's population is set to grow from 8.6 million today to ten million by 2030. By then, we would expect construction to be well underway on schemes such as Crossrail 2, linking south-west and north-east London. Decking over existing roads or creating a replacement ring road, in the form of an inner orbital tunnel or two cross-city tunnels, could enable more efficient and reliable vehicle movement, reducing congestion in central London by up to 20 per cent."

KAREN ANDERTON
RESEARCH FELLOW, TRANSPORT STUDIES UNIT, UNIVERSITY OF OXFORD

"We'll think more about door-to-door trips using things we already consider public transport – buses and trains – and also shared cars and bikes. Real-time information about when services are running, where shared bikes and cars are available, and how much a total trip will cost will be collated on one system. We'll start to think about including ultra-low-emission driverless vehicles in the service too, and it will all be accessed using an Oyster-type card."

ANDERS EUGENSSON
DIRECTOR OF GOVERNMENTAL AFFAIRS, SAFETY STRATEGIST, VOLVO

"The development of vehicle automation will reach a level where individual mobility and public transportation will begin to merge. Public transportation will gradually phase into a network of meshes with different sizes of automated vehicles on offer, each dependent on the number of passengers and type of journey. Larger vehicles will be used for trips taken on main roads and highways, with smaller, passenger-sized ones suited to regular streets."

DANIELA RUS
SINGAPORE-MIT ALLIANCE FOR RESEARCH AND TECHNOLOGY

"Public transportation will become a utility: available anywhere, anytime. A network of vehicles will provide transportation over long distances. There will also be fleets of pods for short hops and for the first- and last-mile part of long journeys. The transportation network will be connected to the IT infrastructure to provide mobility on demand, facilitated by self-driving vehicles. Taking a driverless car for a ride will be as easy as using a smartphone."

ILLUSTRATION: CUN SHI

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Author and broadcaster
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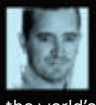
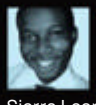
Martha Lane Fox
Crossbench peer
Serial entrepreneur Lane Fox is a crossbench peer in the House of Lords and chair of digital skills charity Go ON UK.

Frank Pearl
Peace Process Negotiator
Pearl worked with ex-members of the Revolutionary Armed Forces of Colombia to re-integrate them into society.



Ryan Weed
Co-founder & CEO, Positron Dynamics
Weed is developing the world's first antimatter rocket to help humans become a truly interstellar species.

Meg Schwamb
Planetary scientist and astronomer
Schwamb is crowdsourcing big science, such as the search for new planets outside our Solar System.



Freeman Osonuga
Ebola-fighting medical doctor
Osonuga worked in Sierra Leone for six months on the front line against the Ebola epidemic in Sierra Leone.

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APPS OF THE MONTH

WIRED

GREAT LITTLE PLACE

This swipe-and-discover app is a great tool for discovering cool places to eat and drink that are off the beaten track. We particularly like the Shortlist and Little Black Book features. *iOS, free greatlittleplace.com*

ENLIGHT

Enlight is one of the smartest photo-editing tools around. As well as a raft of regular features, you can add text in multiple fonts and turn photos into graphics or LOLtastic memes. *iOS, 79p enlightapp.com*

WETRANSFER

If you're already familiar with WeTransfer, then you'll know how useful this file-sending service is. This smartphone version is perfect for those who operate across multiple devices. *iOS, Android, free wetransfer.com*

ONE DROP

Designed for people living with diabetes, *One Drop* can be used to track medication, food intake, glucose levels and exercise. Users can leave advice and feedback based on their own experiences. *iOS, free onedrop.today*

HANDPICK

Handpick harvests recipes from food blogs and *Instagram* and allows the user to browse based on ingredients. It's packed with beautiful photography and inspiring ideas. *iOS, Android, free handpick.com*

WEIRD

MY IDOL – 3D AVATAR CREATOR

This app turns your selfies into animated characters. Dress up in digital outfits and share your dancing avatar. One problem (for UK users): it's in Mandarin. *iOS, Android, free myidolapp.com* **Katie Collins**

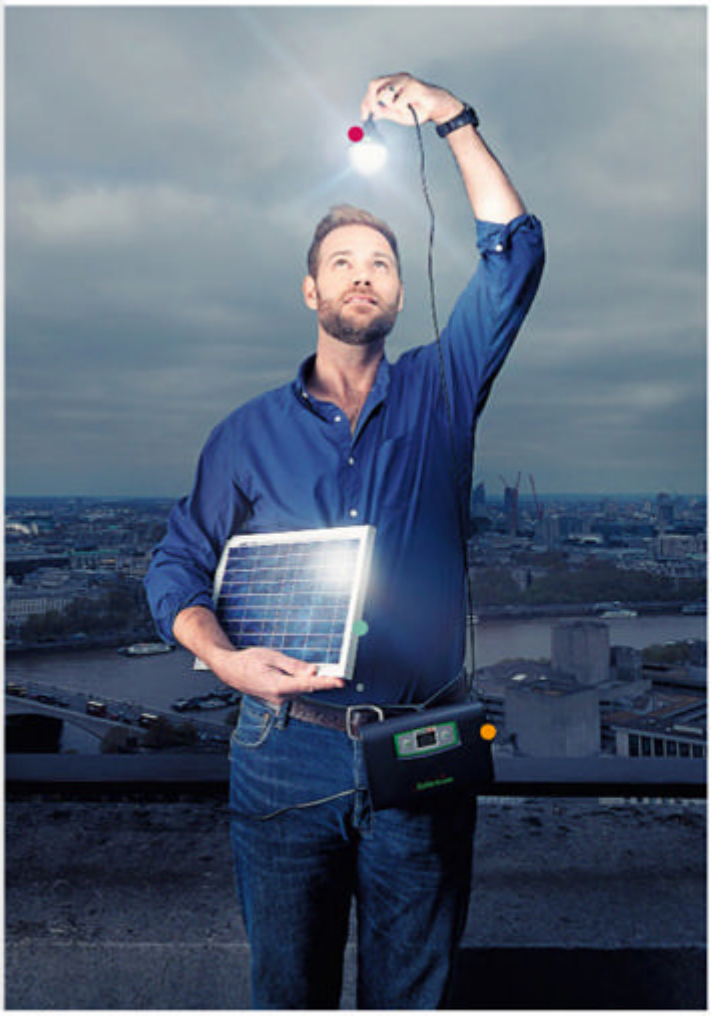
Kenya's solar power broker

Jesse Moore has a bright idea: to offer a cheap off-grid alternative to kerosene

IN KENYA, 70 PER CENT OF ALL CITIZENS – SEVEN MILLION HOMES – LIVE OFF the electric grid. Canadian entrepreneur Jesse Moore (*pictured*) wants to help, so he built M-KOPA, a pay-as-you-go solar-power system. "Our idea was if we can sell a solar system on credit, it will be far cheaper and cleaner than kerosene," Moore explains. "You provide a down payment of $30 [£20], and take home an 8W solar panel and a plug-and-play lighting and charging unit." Since launching in October 2012, M-KOPA, which has partnered with Kenyan mobile operator Safaricom and mobile money service M-Pesa, has sold its system to 200,000 homes across Kenya, Uganda and Tanzania, and is growing at a rate of 15,000 new homes a month.

Moore, 36, says he is not pushing M-KOPA as an environmental alternative – the use of kerosene is purely uneconomical. "Each household spends about five per cent of its income, roughly 63 cents a day, on kerosene, and they still have to go to a shop to charge their phones for another 20 cents a day," Moore says. In M-KOPA's case, once $200 of credit has been paid through the system, the household owns a unit permanently.

With $40 million in funding from a mixture of venture capitalists, debt financiers and grants from nonprofits such as the Bill and Melinda Gates Foundation, Moore's plan is to grow into markets such as Nigeria, South Africa, the Philippines – any country with sunshine and a need for power. "This is going to be a multi-billion-dollar industry," he says. "So many people want affordable solar power and the grid won't be their solution. This industry is unfolding in real-time." **MV** *m-kopa.com*



WHAT'S IN THE M-KOPA BOX

- Two LED lights with switches and brightness settings
- **A4-sized 8W solar panel that fits on a roof**
- Control box with Li-ion battery, SIM card and modem
- **+ USB port and charging ports for four LED lights**
- + A portable solar-powered torch light and a radio

PHOTOGRAPHY: NICK WILSON

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recalibrating every business

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One giant leap for tailoring

Our series on manufacturing visits a spacesuit maker

TOOLKIT

▼

LAUNCH CHAIR
This simulator is used to test how the suit feels when the astronaut is sitting in the launch position. The tester can try to control the simulation while strapped into the four-point harness: "There's a monitor that comes right up towards the face," says Ted Southern. "The subject can also interact with a joystick and a keyboard."

UNLIKE BIG SPACE OPERATORS SUCH AS NASA AND THE UNITED LAUNCH Alliance, Final Frontier Design has just four employees. "It's a long road from a couple of guys in a closet to sending suits into space," says Brooklyn-based co-founder Ted Southern. Although its spacesuits haven't yet left our atmosphere, the team proved their space chops last year when they were selected as one of Nasa's four commercial space partners. Southern, 37, whose background is in costuming, and his co-founder Nikolay Moiseev, 52, who has been making spacesuits since the 80s, formed their partnership after both lost a Nasa space-glove design competition in 2007. They paired up and won the next one, and now they build bespoke suits for customers including high-altitude test pilot Miguel Iturmendi and Barcelona-based near-space flight developer zero2infinity. "We're building a next-generation spacesuit," says Moiseev (the suit is 50 per cent lighter than Nasa's current model). "We achieved this because we are so different – the fusion of our experience has helped us create a new product."

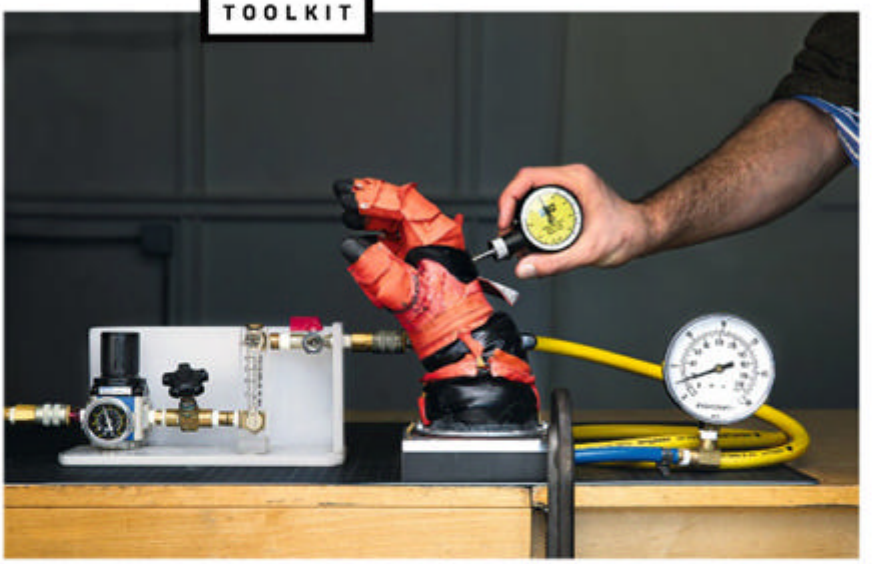
The developments are not only appropriate for space: "We are also looking beyond space-suits to spin-off technologies that are useful on Earth," says Southern. Current projects include a haptic navigation belt, a super-lightweight ski jacket, gloves for firefighters and inflatable costumes for Cirque du Soleil's *Michael Jackson ONE* show in Las Vegas. ("Our leak requirements for Cirque du Soleil are stricter than Nasa's," says Southern.) WIRED takes a tour of the startup's Brooklyn factory. **Sophia Epstein** *finalfrontierdesign.com*

▲

SEALERS
The components of the spacesuits' inner layer need to be sealed together as securely as possible. Each piece of fabric is cut into shape using a laser cutter and cleaned before being fused together by these welders, converted from soldering irons by adding 3D-printed steel tips and Kapton tape covers. >

PHOTOGRAPHY: MARTIN ADOLFSSON

TOOLKIT



◀ ▲

GLOVE TESTING

"Over the years we've had three contracts with Nasa working on extravehicular activity [EVA] components," says Southern. The first was for gloves, then for a pressurised elbow and shoulder component, and an outer garment with integrated radiation shielding. The vacuum-chamber glove box (*above*) was handmade at Final Frontier Design. "It's a big cylinder that we pull the air out of to recreate the pressure differential in a space suit," he says. "It allows us to test them without having to put on the whole suit." (*Left*) Southern tests the torque of a glove's wrist flexion using a hand-held force gauge.

▶

SEWING MACHINES

These sewing machines are used specifically for stitching together the flameproof, tear-proof, orange outer layer of Final Frontier's spacesuits. "We need to use an industrial machine because there are thick layers of Kevlar and webbing to get through," says Southern of the Juki device pictured to the right. The four-stranded BERNINA Serger machine to its left is used to finesse and finish the edges inside the garment.

Flying to new heights

IN THIS SERIES, INVESTEC PRIVATE BANKING EXPLORES THE PEOPLE BEHIND SOME OF THE UK'S MOST EXTRAORDINARY COMPANIES

Luxury watches. It's likely that phrase conjures an image in your mind of Swiss timepieces, assembled by the steady hands of an elderly gentleman. It's the job of Giles English, cofounder of Bremont Chronometers, to change that.

"We're one of the few British watch manufacturers making high-end mechanical watches today," he says. "We've got this amazing history of watchmaking in the UK, and I think that really differentiates Bremont."

English founded the company in 2002 with his brother, Nick, shortly after the death of their father, Euan, in 1995. Nick and his father were piloting a 1942 Harvard plane when it crashed; Nick escaped breaking over 30 bones, but sadly, Euan English lost his life.

But their father didn't just reveal the fragility of life to his sons – he also instilled in them a passion for watches, planes, cars and all things mechanical.

"My dad was this amazing PhD aeronautical engineer from Cambridge who loved building things – whether it be boats, planes, guitars. But one of his passions was watches and clocks," says English. "Nick and I had always talked about watches, but it was just a bit of a fantasy. Post dad dying, I lived thinking I could be dead tomorrow. And I've been through a plane crash since, so I still live very much by that motto."

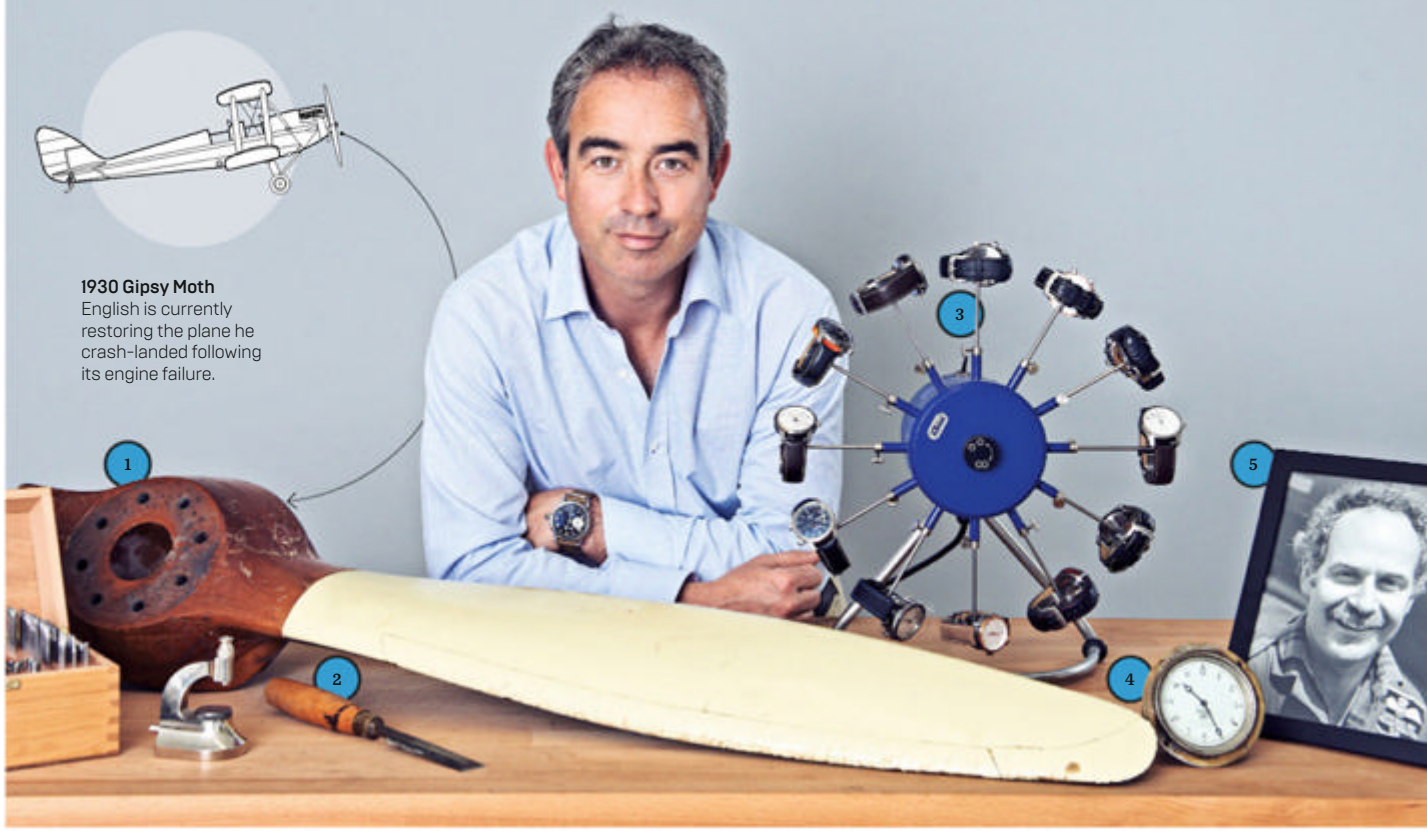
Bremont is taking on the giants of Swiss watchmaking by investing in UK talent and manufacturing. Its Henley-on–Thames HQ houses fresh-faced watchmakers – many the result of the company's apprentice scheme. The English brothers have also built a metal-machining facility that can produce movement parts to an accuracy of two microns – thinner than a human hair.

The pair work on the early sketches of every model before assembly by skilled watchmakers. The resulting chronometers are subtle, stylish and hard-wearing. But to English, they're more than just luxury items.

"It's lovely to actually create something tangible you can wear that'll last forever," he says. "There are very few things you can buy today that really do."

And the name? The brothers were once forced to emergency land in France. A farmer gave them sanctuary, hiding their plane from police and welcoming them into his house filled with clocks. This French ex-pilot had a taste for risk, excitement and mechanics. Monsieur Bremont was the perfect namesake.

Objects from which Giles English draws his inspiration:
1. The remains of his crashed Gipsy Moth's propeller.
2. His father's woodworking chisel.
3. Watches winding on a windmill.
4. A clock by Smiths, a defunct British manufacturer.
5. Euan English, Giles's father and mentor.



1930 Gipsy Moth
English is currently restoring the plane he crash-landed following its engine failure.

PHOTOGRAPHY: CHARLIE SURBEY

STIMULATION STATION

Can't get to the doctor? Receive your neurostim-session via telemedicine

THIS IS NOT A SWIMMING CAP – IT'S A wireless brain-helmet that can measure and electrically stimulate your neurons. "The cap has eight electrodes that allow doctors to monitor the brain remotely via EEG signals, and also send in controlled electrical currents to the brain," says Ana Maiques, co-founder and CEO of Neuroelectrics, the Barcelona-based company behind the cap. "You can diagnose diseases by looking at the brainwaves, and treat certain illnesses by exciting or inhibiting neural activity." Treatable diseases include severe depression, epilepsy, neuropathic pain and post-stroke motor rehabilitation.

The €10,000 (£7,000) devices have been sold to research institutions and clinics in more than 35 countries. "Veterans' hospitals in the US use it to research post-stroke and PTSD treatment, and we are working with Nasa to research brain fatigue," says Maiques, 43. Last year, Neuroelectrics – which launched its cap in 2012 and has been profitable since 2013 – sold €1.5m-worth of devices and is growing at 50 per cent every year.

Maiques's ultimate goal is to get the helmets into patients' homes. "Repeated stimulation makes the brain more plastic, and the effects of the treatment last longer," she says. "If we can send patients home with the device, doctors can treat them over six months, compared to two or three weeks at a time." Even in a patient's home, the device is always controlled wirelessly by a doctor who can remotely apply two-milliamp currents for 20 minutes at a time. The patient's EEG responses are uploaded via Bluetooth into a virtual clinic.

The device is certified for medical use in Europe and is being tested for home use by clinics in Barcelona and Lyons. "I want to expand its uses and enable early diagnosis and treatment of conditions such as Alzheimer's." **MV** *neuroelectrics.com*

PHOTOGRAPHY: DANIEL LOEWE

WIRED	TIRED	EXPIRED
Pay-per-view on Periscope	**Your dad's Netflix**	Megaupload downloads
Verizon-AOL	AOL-Time Warner	**Yahoo!**
Cold brew & tonic	**AeroPress-SodaStream**	Regular black
Slack cabals	Hidden IRC	**Secret listservs**
BB8	**R2-D2**	AIBO

Industry in sync

IN MAY, WIRED AND ACCENTURE HOSTED THE SECOND OF FOUR BY-INVITATION EVENTS, EXPLORING THE BIG TRENDS OF THE NEAR FUTURE. THE TOPIC OF DISCUSSION: THE INDUSTRIAL INTERNET OF THINGS

Accenture estimates the Industrial Internet of Things (IIoT) could add $14.2 trillion to the global economy by 2030. With such numbers at stake, WIRED and Accenture invited a select group to a London event to discuss what happens when you connect every aspect of industry – from production to consumption, and everything in between.

The dinner and debate, preceded by a WIRED-curated technology exhibition, was led by WIRED editor David Rowan and Ben Salama (*right*), who leads Accenture Digital's Connected Operations practice around the world.

"When you look at industrial companies, connected products and devices are not new," he says. "But the Internet of Things is showing that these don't need to be siloed off anymore. On the contrary, now they're going to be connected in a broader way – so you can connect the top floor with the shop floor."

This allows for a company to act as a single entity, says Salama, rather than as a collection of separate departments. The data generated by sensors and mined by centralised systems can help highlight inefficiencies and reveal new prospective revenue streams.

Event attendees looking to discuss such ideas included government officials, founders and heads of business. Around the table sat Jason Ball, investment director at Qualcomm Ventures; Ed Vaizey, the Digital Economy Minister; Duncan Wilson, director of the Intel Collaborative Research Institute; Steve Unger, acting chief executive of Ofcom, and many other business leaders.

Aspects of the IIoT which sparked debate included the huge potential for connected health, when and how the "killer app" of consumer wearables will take shape, the potential for real-time risk analysis, and how cryptocurrencies can help both governments and citizens.

For Salama, the big shift will be how the IIoT helps companies redefine their businesses. "The classic ideology of 'we build a product, then sell it' will be gone." *Visit accenture.com/technologyvision*

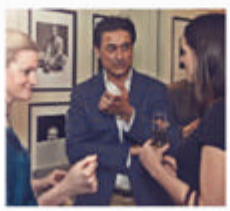
PHOTOGRAPHY: CHARLIE SURBEY

PRE-DINNER TECHNOLOGY EXHIBITION

Ed Vaizey, the Digital Economy Minister (*centre*), speaks with David Rowan, WIRED editor (*left*), and Azmat Yusuf, CEO of CityMapper (*right*) ahead of the co-hosted dinner.

Cédric Hutchings, CEO of Withings (*left*), with Will Cavendish, director general of innovation, growth and technology, at the Department of Health (*right*).

Jason Ball, investment director of Qualcomm Ventures (*centre*), examines Netatmo devices, including a smart thermostat, a UV-sensing wearable and a security camera.



Sophie Hackford, director of WIRED Consulting and Education (*left*), with Narry Singh, managing director of digital business strategy at Accenture (*centre*) ahead of the dinner.

Jeep

COULD IT BE ANY MORE PERFECT?

There's not a single cloud in the sky and yet it's the Jeep Grand Cherokee that really shines. With its dynamic looks, luxurious interior, innovative technologies and strong, yet efficient engines things really don't get any better. Perhaps that's why it's the most awarded SUV ever.* And should the weather take a turn for the worse, you can always turn on the heated seats.^

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Jeep, with EXPO MILANO 2015

Model shown is a new Jeep Grand Cherokee 3.0 litre V6 Summit. OFFICIAL FUEL CONSUMPTION FIGURES FOR THE NEW 2014 JEEP® GRAND CHEROKEE DIESEL RANGE IN MPG (L/100KM): EXTRA URBAN 43.5 (6.5), URBAN 30.4 (9.3), COMBINED 37.7 (7.5), CO_2 EMISSIONS: 198 G/KM. Fuel consumption and CO_2 figures are obtained for comparative purposes in accordance with EC directives/regulations and may not be representative of real-life driving conditions. Factors such as driving style, weather and road conditions may also have a significant effect on fuel consumption. *Claim relates to the Jeep Grand Cherokee nameplate over its lifetime. **Promotion available on Grand Cherokee models registered by 30th September 2015. 0% APR Representative Hire Purchase available for a 3-year term with a minimum deposit of 10% required. Finance subject to status. Guarantees may be required. Terms and Conditions apply. Jeep Financial Services, PO Box 4465, Slough, SL1 0RW. ^Excludes Laredo model. Specifications are correct at time of going to press (06/15). Please visit jeep.co.uk for latest information. Jeep® is a registered trademark of FCA US LLC.

IDEAS BANK

ALEXA CLAY &
KYRA MAYA PHILLIPS

Startups could use some more ex-cons

The story of tech entrepreneurship is dominated by variations of a very familiar, overused persona: the hoodie-wearing college dropout, the socially awkward geek wunderkind, and, increasingly, the beer-guzzling bro. Catch an episode of Sky Atlantic's *Silicon Valley* and you'll find these characters in spades. The trouble with focusing only on the Zuckerbergs of the world is those stories we leave behind: the entrepreneurs whose tales don't begin with a passion for computer programming and don't end with a nice IPO.

Fabian Ruiz, a former prisoner from New York, spent 21 years in prison for killing a man he believed had shot his brother. Inside prison, Ruiz started a magazine covering hip-hop and prison news. He also learned plumbing and how to carry out electrical work, and studied liberal arts and law. When we met him, Ruiz was out of prison and a participant in Defy Ventures, a New York City-based nonprofit programme designed to help ex-offenders "transform their hustle" by connecting them with training and opportunities to become entrepreneurs in the legal economy.

Today, you can find a few programmes of this kind designed to help inmates and ex-offenders rebuild their lives. Free Minds Book Club in the US, founded by two former journalists, uses books and creative writing to support juveniles who were incarcerated as adult offenders. In the UK the Small Business Consultancy, founded by Amar Lodhia – a former addict who was kicked out of school at 17 before becoming homeless – has a mission to help people with similar backgrounds, many of them ex-offenders, kick-start their own entrepreneurial endeavours. The hope is that ex-offenders will not only fail to reoffend, but also that they will use the lessons they learnt on the streets to build their own organisations and potentially become employers themselves.

Ex-offenders have invaluable experiences, thought processes and skill sets that can help to make them successful entrepreneurs. Duane Jackson is one example – he grew up in a children's home in east London, dropped out of school and then at 19 was arrested for attempting to smuggle 6,500 ecstasy tablets into the US. After serving two years in a UK prison, he faced the daunting task of finding a job. Struggling to get someone to hire him, he decided to make use of his self-taught coding skills and start his own company, KashFlow, to provide online accounting software. It eventually grew to employ 40 people and produce annual revenues of nearly £2 million. In 2013, Jackson sold the company to IRIS, a large provider of business and accountancy software. Drawing on his experience in criminality, Jackson understood that entrepreneurship called for an ability to calculate risk, an understanding of his competition and the value of forging a set of strategic alliances.

Alexa Clay and Kyra Maya Phillips are the authors of *The Misfit Economy* (Simon & Schuster)

The mindset of an ex-con capitalises on the hustler's instinct – the ability to make something out of nothing. During our interview with Ruiz, he rose from his chair and asked us to look around the room we were sitting in. He said: "There are at least 100 weapons in here." He pointed toward a plastic chair, which he said he could melt and turn into a razor. He continued to survey the room, telling us that the metal rod on the TV stand right in front of us could easily be fashioned into a sword. The entire plumbing system of the building? An arsenal of weapons. The sink in the corner? He could kick it, he said, and make a knife out of the >

ILLUSTRATION: NICK LOWNDES

porcelain. What to us would be invisible, or useless, or completely taken for granted, is to someone with Ruiz's experience obvious, useful and essential. What around us are we ignoring, and how could we productively make some use of it?

The startup world has been criticised for creating products and services that solve problems only the techno fortunate are privileged enough to have. Getting your laundry picked up with the press of a button; hiring a cleaner via an app; securing a date with someone who lives or works nearby; finding a taxi. In contrast, formerly incarcerated individuals bring a different perspective.

Solving real-world problems is not something for which Silicon Valley entrepreneurs have always been praised. Ex-offenders, however, do tend to think about issues that impact their own communities. More recently, Ruiz has set up a business to deliver internet information to those in prison who have restricted access. He remembers his thirst for knowledge and information when he was locked up, and sees in addition to the social service a good market opportunity. This sort of fusion – a social service coupled with a market opportunity – gives an entrepreneur an edge in a world accustomed to focusing mostly on the latter.

NICK BEIM

Venture capitalists need to get more female friendly

There is an uncomfortable truth in the venture capital industry that runs awkwardly against its meritocratic aspirations: it is harder for women to raise money than it is for men. Since 2005, only 9.7 per cent of venture-backed founding teams in the US have included a woman, and far fewer were led by one. Other data suggests a similar conclusion, but the conclusion is similar to most.

What's the reason for this? Rarely, but sometimes, I've seen it come from an unabashed bias about women's ability to be as productive as men. Generally this relates to concerns that having or raising children will be a distraction. I believe this kind of bias is in substantial decline, however, as younger generations of investors rise to prominence.

More often, I've seen it result from a bias rooted in the primary way venture capitalists make decisions, which is through pattern recognition. As one investor puts it: "Most successful startups are started by men in their 20s and 30s; the number of successful startups founded by women is much smaller." Yes, but most startups throughout history were started by men in their 20s and 30s. This doesn't speak to the likelihood of women succeeding, particularly since more women are starting companies today than ever before.

Social scientists call this logical flaw *selecting on your dependent variable*: determining that A is a principal cause of B by looking only at cases of B. Used as a lens for evaluating investments, it is the reason most venture capitalists are late to promising new trends and only jump on board when there is a significant pattern of success.

This is the cause of the biggest challenge that female entrepreneurs face in raising money. Most venture capitalists haven't internalised the success of female entrepreneurs to a sufficient degree to have it influence their intuitive pattern recognition, partly due to what they perceive as a lack of a large enough *n* (or sample size) and partly no doubt because they have not worked with female founders directly.

Nick Beim is a partner at Venrock in New York and was the initial venture investor in Gilt Groupe and Care.com, among others

The number of women entrepreneurs is growing, however, as is the success of the companies they've founded. Consider just the following handful of companies, together worth more than $60 billion (£38bn): Epic Systems, VMWare, EventBrite, Theranos, Genomic Health, Net-a-Porter, lynda.com, Gilt Groupe, Minted, Care.com and Houzz. If one does not see a pattern in these examples, I think it may be due to lack of awareness of the facts.

The success of these and other female-founded companies is precisely what will finally move the needle for the silent majority of venture capitalists stuck on historical pattern recognition. They will represent a pattern to be ignored only at one's peril. It's only when venture capitalists fear they are going to miss out on something big that their behaviour changes. More women in the venture capital industry will definitely help as well, in particular because they tend to spot trends in female-dominated industries faster than men.

Remember all those VCs who thought it would be a challenge to make money on the internet, in social media or in mobile? Those debates have been definitively won and lost, and today everyone invests in these areas. Those harbouring concerns about investing in female entrepreneurs will increasingly abandon those concerns in the face of significant and growing data relating to their success.

For all the problems the venture industry has investing in female entrepreneurs, there are some investors who do support them. And often this works out particularly well for them, given the biases mentioned above. I've made five investments in companies founded by women, and they include some of my best. In the long term, markets do tend to be efficient. The success of these and other female entrepreneurs will erase the biases that women have to fight today.

ILLUSTRATION: MICHAEL ARNOLD; YAKAI DU

ROBIN CHASE

Want continued exponential growth? Better start collaborating

The pace at which glaciers have actually melted is faster than the pace of our economies addressing climate change. After decades of ineffective response to increasingly urgent cries of alarm about this "absolutely unprecedented emergency" (Blue Planet Laureates), and the need to avoid "irreversible catastrophic effects" (James Hansen), climate realists like myself are worried that we actually have run out of time.

The world population is seven billion and growing. Getting CO_2 emissions to peak immediately (rather than grow at two per cent a year), and start a rapid reduction in each succeeding year in order to hold a 2°C increase (the threshold scientists say could avoid the worst effects of climate change), is feeling increasingly implausible without a miracle.

Yet although the door for action in the traditional plodding way may have shut, a window for miracles has appeared. Over the last two decades access to the internet has permeated and impacted our business models. We are witnessing the rise of a new organisational paradigm I call Peers Inc. Zipcar, which I co-founded, taught me the lesson when we applied technology to make renting cars for as little as an hour at a time as easy and convenient as owning your own. The internet has taken the pain out of dealing with many small pieces; transaction costs are close to zero. A totally new approach to organising resources is now possible.

You will recognise the movement's fingerprint in well-known institutions and movements such as Facebook, YouTube, Google, Airbnb, Uber, Yelp, Wikipedia, massive online open courses, smartphone apps, 3D printing, open data and free and open-source software. In each, three components are the building blocks of success: the harnessing of excess capacity; a platform for participation that organises and empowers; and a diverse group of participating peers.

Robin Chase is co-founder of Zipcar and Veniam and author of *Peers Inc* (Headline)

Airbnb's extraordinary growth – in just four years the company offered up the same number of beds for rent as the InterContinental Hotels Group, the largest hotel chain in the world, mustered in 65 years – was due in part to coupling the excess capacity found in idle housing assets with a beautiful and compelling platform that gave homeowners the look, feel and technical skills of professionals. A similar potential for exponential growth, using the same principles, can be found in small-scale solar power. More than 600,000 homes and businesses in the US have installed on-site solar since 2000. Growth has been 50 per cent year on year in each of the last three years, with almost 200,000 installations in 2014. What happened? Instead of homeowners spending months to figure out the financing, best hardware configurations, contractors and relevant tax benefits, Sun City, Sungevity, Solar Mosaic and others have been perfecting web platforms that make signing up alluring and simple. Just as Airbnb gives the power of the corporation to its "hosts", so too do these one-stop-shop solar companies empower the small property owner. And, like Airbnb, the resulting collaboration enjoys the improved economics of the excess capacity to be found in free rooftops and the guaranteed purchase of most of the power generated by the owner.

Before there was Waze – a good example of a Peers Inc-inspired app-based crowd-sourced navigation system – companies used to muscle traffic data out of roadside sensors, traffic counts and well-positioned speed cameras. Waze transformed this heavy lift by leveraging the sensors and GPS within each individual driver's smartphone to deliver better speed and routing results, and in real time. So too can big data services – generally making use of data that already existed but was simply unvalued and unexamined – rapidly transform the energy efficiency of most buildings. A 2010 McKinsey study estimated that 23 per cent of energy demand in 2020 could be reduced through the application of big data to energy efficiency. Again, a deep collaboration is involved. Platform algorithms examine the mountains of data from both individuals and communities of individuals, recognise patterns and design beautiful and useful ways for us to quickly interact with this now empowering data. Energy-management >

systems such as OPower (targeting utilities), SkyFoundry (companies) and Nest (individuals) are all striving to make it simple and convenient to take our data and turn it in to immediate personal, hyperlocal energy reductions. Big data also offers us the power of exponential learning, if the platforms make use of the thousands and millions of transactions that pass through their servers.

Such collaborations also permit us to find just the right expertise we need at just the right time. Yelp reviewers tell me about my local hardware store. Trending Twitter hashtags give me eyewitness updates of unfolding local crises. Brilliant experts in diverse fields solve the "unsolvable" problems of Nasa and Pfizer using InnoCentive. Platforms let us identify and make use of people's deep nuanced experience. Recently, 350.org developed an extensive and multilayered campaign around divestment from fossil fuels. You might think that this is organising such as it ever was, but actually it is something new: 350's campaign almost always requires specific customisation and localisation of the programme. It relies on the participating peers to add their own individuation of the campaign under way. Thus we see students provoking Harvard University, *The Guardian* overlaying a black, oily pop-up over its website's home page, and people in 60 countries at 450 different events calling attention to themselves on Global Divestment Day.

The movement's organisational structure relies on a solid, synergistic, complementary collaboration between the big Inc (governments, organisations, and institutions) and the small peers (individuals and local companies in every nook and cranny of the world). It is this collaboration that can produce the miracles. Together. None can succeed alone.

This is what gives me hope, what fills me with optimism. With the right structure – excess capacity, platforms, peers – we can scale transformations at exponential speed. We can learn at an exponential pace and we can count on solutions being adapted for each unique situation around the world. We can break out of those depressing and implausible trend lines and chart a whole new path.

JENNIFER JACQUET

Public shaming makes the world a better place

The discussion about 21st-century shaming usually turns to cases in which an otherwise well-behaved person posts a tweet or photograph that results in excessive punishment by an anonymous and bloodthirsty online crowd which ruins that person's life for a while. Many people, myself included, object to this form of vigilantism. But other examples of shaming – singling out big banks for environmental destruction, exposing countries for refusing to end forced labour or calling out denialists who undermine action on climate change – challenge the mistreated tweeter as shaming's stereotype. What shaming largely is, after all, is not necessarily what shaming might be.

Jennifer Jacquet is an assistant professor at New York University and author of *Is Shame Necessary? New Uses for an Old Tool* (Allen Lane)

Some recent cases of shaming show us how social disapproval might be wielded in considerate and effective ways. Non-profit groups, including Netherlands-based BankTrack, have spent the last five years calling out the worst banks funding mountaintop-removal coal mining in Appalachia, which is environmentally destructive but not yet illegal. After being exposed, several banks vowed to phase out their relationship with mountaintop removal, thus demonstrating the power of shame to work at large scales. (In contrast, Barclays actually scaled up its financing and in 2013 became the number one financer of mountaintop-removing coal companies with 12.5 per cent of market share. Expect to see strategic shaming of Barclays in the future.)

Shaming retailers and even countries can sometimes trigger big changes before legislation is in place. In June 2014, *The Guardian* reported on slave labour in Thailand's shrimp industry and named large retailers which sold slave-prepared shrimp, including Tesco. An official spokesman for Prime Minister David Cameron said that it was "up to consumers whether they chose to eat prawns that had been produced through the work of slaves". Saddling consumers with the government's job is a Machiavellian approach to addressing social problems. Even without government action, retailers understood that the problem had to be addressed, and Tesco pledged to "ensure the supply chain is slavery-free". The story landed the day before a vote in Geneva to adopt a new treaty to ban forced labour around the world. Thailand opposed it but, after public opprobrium, went back on its decision.

Several studies, including one my colleagues and I conducted, have shown that singling out bad apples in social dilemmas can lead to greater co-operation. Polls show that the vast majority of Americans, including half of Republicans, believe we should take action on climate change, but members of Congress block legislation. Recently, non-profit group Organizing for Action made it easy to call out climate denialists in the US Congress privately over email or publicly over Twitter, and even hosted a climate-change fantasy tournament between the 16 worst climate denialists in Congress.

Digital technologies have made it possible for each of us to instigate online shaming – and each potentially become its victim – but more important, we are now asked every day which issues matter enough to weigh in on. Given the limited nature of attention, and how essential attention is to shaming's effectiveness, we must ask ourselves which issues to prioritise. We might share concerns about a shame-filled world that leads to individual suffering and worry that punishment online is disproportionate and lacks due process. But shaming, aimed well, cautiously and at the right time, can improve society.

ILLUSTRATION: SERGIO MEMBRILLAS

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The Bupa Startup Stage

FROM MENTAL HEALTH SUPPORT TO EARLY DIAGNOSIS, WHO CAN MAKE THE BIGGEST IMPACT ON HEALTH?

Away from the Main Stage at WIRED Health on April 24, a special gathering took place. For three sessions, 17 companies came together – in front of an audience of investors and delegates – to share their visions for the future of healthcare.

The Bupa Startup Stage, hosted by WIRED's associate editor Madhumita Venkataramanan, was a platform for growth stage companies in the sector to explain their journeys and business models. The aim was to spread ideas and for the founder of each company to pitch for a spot on the Main Stage at the end of the day.

"The purpose of Bupa is longer, healthier, happier lives," said Garry Fingland, chief information officer at Bupa, speaking with Venkataramanan. "What we see here is an opportunity to really think about how new technologies and innovations can contribute to that purpose."

In the morning session, the audience heard from stress monitoring and managing tools, SOMA Analytics and The PIP, before listening to the likes of Buddy Enterprises, a smartphone-based support tool for people with mental health problems, and the *GoodSAM* app, a platform to alert nearby medical professionals when an emergency is reported.

After lunch, NaturalCycles pitched its model for drug-free pregnancy prevention, and Klarismo revealed how it is making detailed 3D body-scans available for all. Among others in the final session, MedialCS unveiled its model for the early diagnosis of critical illnesses using big data, MindMaze showed off its neurotechnology platform to assist patients with brain and spinal cord injuries, and MIRA Rehab shared how gamification is helping young people recover from surgery or injury.

Alongside Fingland and Venkataramanan on the panel (*right*) was Martin Kelly, CEO at HealthXL. But picking a winner was never going to be easy.

"Neuroelectrics had the best combination of strong scientific evidence, partnerships with a range of organisations – from universities to Nasa – and a solid business model," says Venkataramanan. "We felt it would make the most impact in the near future." *See bupa.com/mhealth*

Clockwise from top left: **Leading VCs and event delegates in the Startup Stage audience; Ana Maiques, CEO of winning startup Neuroelectrics; Pierre-Emmanuel Meyer of MindMaze; delegates in the packed audience.**

THE BIG THREE: THE JUDGING PANEL'S PICK OF HOT STARTUPS

NEUROELECTRICS

Represented on stage by CEO Ana Maiques, Neuroelectrics has created a diagnostic and treatment telemedicine platform that helps patients recover from issues such as chronic pain or stroke rehabilitation.

PEAK

Peak is a mobile brain-training app that's used by millions to track and improve their cognitive skills with fun and challenging games. The app was founded in 2012 by former Google, Amazon and EA execs, plus physics PhDs.

KLARISMO

Klarismo makes MRI scans available at low prices and helps private medical imaging centres optimise their facilities. It aims to build the world's largest data set of full-body MRI scans, which it will make available for research.

PHOTOGRAPHY: PETER GUENZEL

What we learned from 21 speakers and 17 startups at WIRED Health 2015



MEET THE SPEAKERS

Innovations from prosthetics to brain-stimulating video games were discussed at WIRED's second Health conference, held in London on April 24. The event's key takeaway: personal medical care will embrace data-led preventive strategies and interactive therapeutics for the individual. "We need to start looking at making personalised decisions," says Martin Kohn, chief medical scientist at Sentrian, a startup using biosensors to fight chronic disease, and one of the 21 specialists to speak on the conference main stage. Sophia Epstein







This page, left to right, top to bottom:
Adam Gazzaley Founding director, Neuroscience Imaging Center
Gadi Amit Founder, NewDealDesign
Geoff McGrath Vice president, McLaren Applied Technologies
Nigel Ackland Prosthetics pioneer
Tony Young National director for innovation, NHS England
Matteo Lai Co-founder and CEO, Empatica
Marc Koska Inventor, KI auto-disable syringe
Lama Nachman Principal engineer, Intel Labs
John F Cryan Professor and chair, department of anatomy and neuroscience, University College Cork
Sophie de Oliveira Barata Founder, the Alternative Limb Project


This page, left to right, top to bottom:
Jaan Tallinn Co-founder, Centre for the Study of Existential Risk
Jack Kreindler High-altitude medic
Sonia Trigueros Co-director, Oxford Martin Institute of Nanoscience for Medicine
Rory Sutherland Vice chairman, Ogilvy & Mather UK
Eleanor A Maguire Professor of cognitive neuroscience, UCL
Andy Walshe High-performance director, Red Bull
Sarah-Jayne Blakemore Royal Society university research fellow
Martin Kohn Chief medical scientist, Sentrian
Clive G Brown CTO, Oxford Nanopore
Shahid Azim Co-founder, Quanttus, Inc
Brad Perkins Chief medical officer, Human Longevity









EMBRACE SUBCUTANEOUS BIO TRACKING

Gadi Amit *Taking wearables to a new level*

The Apple Watch might not be the future of wearable technology, says Gadi Amit, founder of NewDealDesign, which created the Fitbit activity tracker and Sproutling (a wearable baby monitor). "There is an idea that if we just load more and more functionality on to our wrists, things will get better. But in many cases, they do not."

Instead of strapping a smartphone to his wrist, Amit is taking a more radical approach. His latest design, Project Underskin, communicates through two "screens" implanted under the skin: a personal screen on the inside of your thumb and another on the back of your hand. The interface is a pentagon that lights up in various patterns to communicate data in a way only you can understand. This glowing "tattoo" could report key health metrics such as glucose levels, as well as exchange virtual business cards through a handshake. *newdealdesign.com*

PLAY VIDEO GAMES TO BOOST YOUR BRAIN

Adam Gazzaley
Proving that entertainment can enrich

Our healthcare system is not personalised enough, explains neuroscientist Adam Gazzaley, and far too simple. "A single pill is used, as if we have a holy grail, a way of meaningfully changing something as complex as the brain," he says. "And we don't have that." His solution: video games, specifically brain-training activities that adapt to your progress to keep challenging key areas, such as multitasking, attention and memory.

His team in San Francisco has already created *Neuroracer*, a simple game that has already improved the multitasking abilities of 60- to 80-year-olds, who after completing 12 hours of the game over a month, three hours per week, outperformed the multitasking abilities of 20-year-olds playing the game for the first time.

"Video games are an immersive, engaging, enjoyable, interactive way of changing behaviour," says Gazzaley. "We think that they can be a positive source of impact, so they're our main delivery tool." His team is preparing for a clinical trial, testing whether the game could be used as a therapeutic for people with ADHD.

To boost the impact of each game, Gazzaley built Glass Brain, a 3D brain visualisation combining MRI and EEG that monitors in real time how brain areas are communicating with each other. At the moment his games evolve based on MRI and EEG observations of the player's performance, but he hopes to be able to feed in this more comprehensive neural information. "By using neural activity and feedback we can apply pressure and change that system." *gazzaleylab.ucsf.edu*

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BIONICS CAN RESTORE THE HUMAN

Nigel Ackland
Bioprosthetic pioneer

"I'm just an ordinary man," says Nigel Ackland, 56, whose arm was amputated in 2007 after an industrial accident the year before. "And I'm fortunate to wear an extraordinary piece of technology."

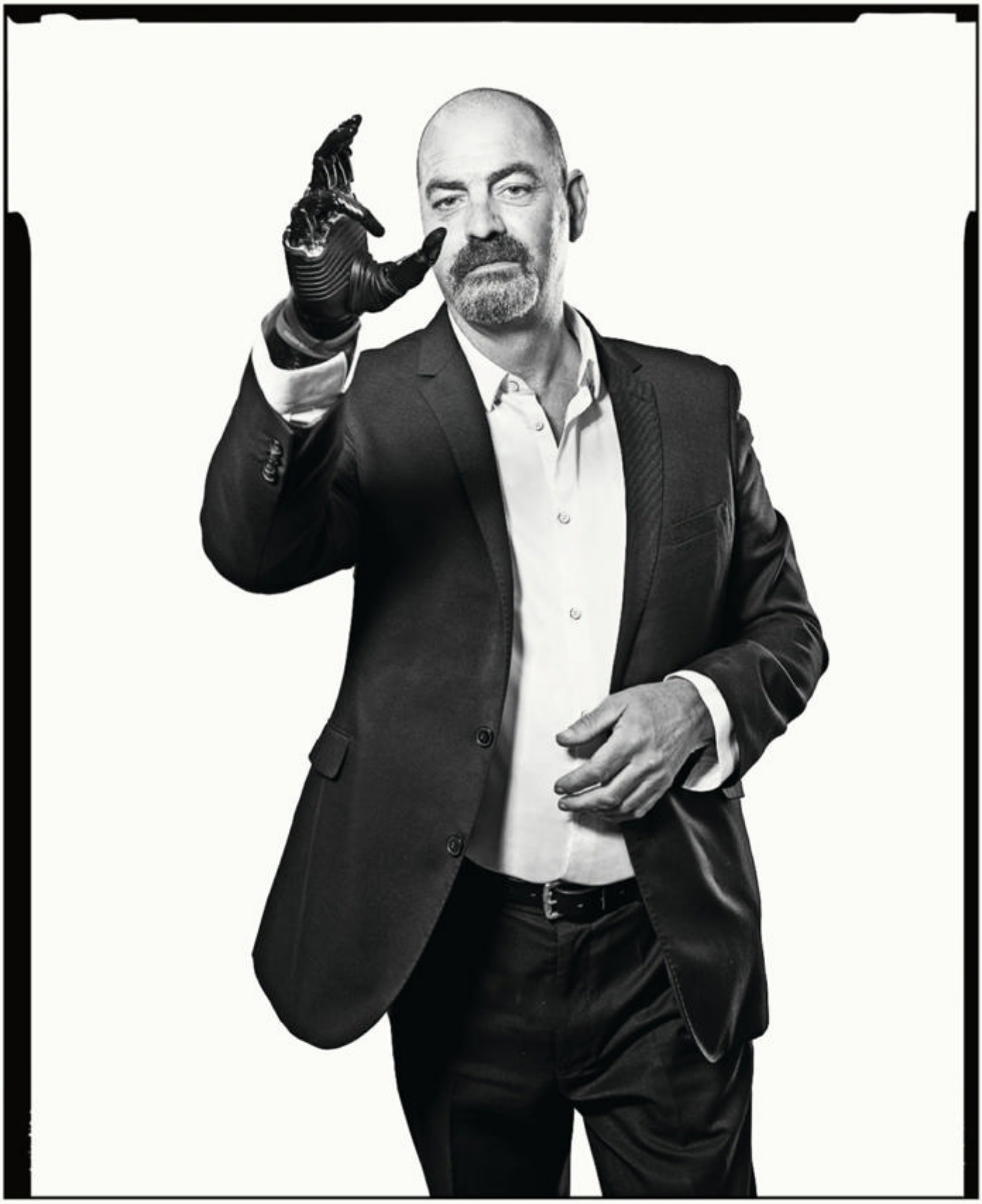
Ackland was the first patient in the world to be fitted with RSL Steeper's Bebionic3 myoelectric prosthesis. It's fast, can lift up to 40kg and has eight functional grips, for everything from a handshake to using a mouse. "But the psychological benefits really outweigh anything this could do," says Ackland. "It makes you feel human again."

Before getting the Bebionic3, Ackland went through the standard three-stage NHS treatment plan – which still makes him grimace. First an ill-fitting passive limb that would fall off in public; then a hook; and finally a greifer – a two-pronged attachment similar to the jaws of a crane, so uncomfortable he could only wear it a few hours a day. "That's what you get on the NHS after three or four years," he says. "If you're lucky."

The pain and frustration took their toll and Ackland – a man who gives no indication of ever having been depressed – describes his past thoughts of suicide. "I used to be the hunter-gatherer, provider for my wife and family – now I struggle to wipe my backside," he says. "Psychologically I'm falling apart."

Since being fitted with the Bebionic3 in 2012, he says his capabilities have greatly improved. "The way I control it has actually evolved," he says. He used to have to consciously think about each movement. "Now, my phantom limb and my prosthetic seem to have been connected by my brain... I feel my thumb lift before the prosthetic moves. It's almost as if I'm reconnecting."

He has also reconnected with the world, after withdrawing from society after losing his arm. It's something he calls the "bionic effect". "When we shake hands, people smile, and it's a genuine smile," Ackland says. "I see that smile as a sign of acceptance for who I am. No one ever asked to shake my hook." *bebionic.com*



‘NO ONE EVER ASKED TO SHAKE MY HOOK’

Nigel Ackland

DITCH THE PSEUDOSCIENCE AND REALISE THAT STUDENTS ARE WIRED DIFFERENTLY

Sarah-Jayne Blakemore
Remembering circadian rhythms

"Neuroscience has already infiltrated education," says Sarah-Jayne Blakemore, professor of cognitive neuroscience at UCL, but not in the way she would like. She raises questions about products, including non-profit classroom tool *BrainGym* which claims children have "brain buttons" – certain areas on their bodies they can push to boost brainpower – and provides exercises to stimulate left-brain/right-brain communication. "What is this nonsense?" asks Blakemore, explaining that the left and right brain are in fact always in constant communication. "It's pseudoscience."

The area of neuroscience that Blakemore believes could help in the classroom is the study of adolescent-brain development. "One thing that we know about the adolescent brain is that it's changing and it's plastic and malleable," says Blakemore. And adolescence is an important time for education – so the system should fit its needs. The body's circadian rhythms shift during puberty because the sleep hormone melatonin is produced later in the day, she explains, so later school-start times for adolescents would be far "more in tune with their biology". *sites.google.com/site/blakemorelab*

HOW STEPHEN HAWKING GOT A VOICE UPDATE

Lama Nachman
Helping the world's pre-eminent physicist be heard

Intel has been supporting Stephen Hawking's communication needs for over 20 years. Its latest Assistive Context-Aware Toolkit was customised just for him. "He wasn't interested in revolutionary," says Lama Nachman, senior engineer of the team that developed the new software. "He wanted something familiar." Hawking uses the interface as before – an infrared sensor on his glasses tracks cheek movement – but an automated system cuts down the duration of simple tasks. The system is open source so researchers can help motor-neurone sufferers and quadriplegics worldwide. *01.org/acat*

'STEPHEN WASN'T INTERESTED IN ANYTHING REVOLUTIONARY'

Lama Nachman

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LIVE LONGER THROUGH GENOME STUDY

Brad Perkins *Data mining for longevity*

The mission of California-based Human Longevity is simple: to extend healthy lifespans. "I don't have a pill, so I'm sorry to disappoint you," says Brad Perkins, the company's chief medical officer. Instead, he's planning on lengthening lives using data. Human Longevity, Inc, co-founded with genomics pioneer Craig Venter, claims the world's largest and most comprehensive human genome-sequencing facility, now capable of sequencing 35,000 genomes per year. That will increase to 100,000 by the end of 2015. "Our focus is to build complete, integrated health records," says Perkins, "and then translate this genomic data into information and patterns." This data can then be used to understand what makes for a longer life as well as what might cause an individual life to be cut short.

"The potential scale of disruption this research could cause is huge," says Perkins of his vision for the future. "By compiling genomic information and subjecting it to machine learning, we will revolutionise our rate of discovery for new therapeutics, new diagnostics and new models for advanced healthcare." *humanlongevity.com*

GO TO PHYSICAL EXTREMES IN ORDER TO LEARN

Andy Walshe
Putting "no pain, no gain" to the test

Before Felix Baumgartner dived almost 40,000 metres through space and back to Earth, he was trained by Red Bull's high-performance director, Andy Walshe. The seven-year project encountered lots of hurdles, and for Walshe that meant the next step was training for the unknown, learning to deal with failures before they arose, whether they be technical glitches such as faulty parachutes or more emotional challenges such as fear. Walshe's next project, Acheron, involved parachuting four elite athletes into the Australian outback in the hope that enduring physical challenges while outside their comfort zones would challenge them holistically – body, mind and spirit – resulting in improvements in their mental and physical performances. Their brains were fMRI scanned while they were tested on resilience, stress and performing under pressure, both before and after the experience. "Even in eight days the shift in the individual is fairly profound," Walshe says.

But these experiences are clearly not scalable. So Walshe is now using neurofeedback headgear to monitor and reinforce positive behaviours in the brain to get the same performance-enhancing effect. "If we can take these lessons from the very best in the world and bring them to the wider community, that would be extraordinary." *redbullstratos.com*

USE MRI SCANS TO SAFEGUARD MEMORIES

Eleanor A Maguire
Defying Alzheimer's disease

"Memory is central to who we are and what we do," says Eleanor A Maguire, professor of neuroscience at UCL and the Wellcome Trust Centre for Neuroimaging. "It is the basis of our culture and we would not have society without our shared memories." Her research into how memory works has brought her focus to the hippocampus, which is located in the temporal lobe of the brain. "We were able to predict or decode exactly which specific autobiographical memory a person was recalling just by looking at the pattern of functional MRI activity in the hippocampus," she says. Her next question: how do these memories get there?

Previous memory research has typically assumed memory is separate from the rest of cognition, says Maguire, but she sees the two as being inextricably linked – referring to studies of patients with amnesia who can no longer create visual scenes. "They are literally stuck with what's in front of their eyes. They have no past, no future and no imagination," she says. "They can't even visualise what's behind them or what might be just around the corner."

Maguire is now looking for new approaches in tackling degenerative brain conditions such as Alzheimer's as well as optimising healthy brain performance. Through her current study MEMO (multifaceted examination of memory and its origins), which will gather MRI data from hundreds of volunteers, she aims to understand how memories are formed, represented and recollected by the brain – and why some of us might be better at it than others. *fil.ion.ucl.ac.uk/memo*

Carbon Black Wheelchair
This wheelchair (*left*), made almost entirely out of F1-spec carbon fibre, is lightweight (8.5kg) and has naturally occurring shock-absorbent properties. Each chair is custom built to the measurements of its user, keeping the design minimalist, and can be easily taken apart without the need for tools. *carbonblacksystem.com*

THE HANDS-ON CLINIC AT WIRED HEALTH 2015

Delegates could explore and interact with a wide range of new healthcare products and devices, including:

Insulin Angel
Diabetics can use Insulin Angel to track the temperature and location of their insulin by attaching the device to their medication. Developed by a diabetic, it will tell you where you've left your meds and monitor the temperature to make sure the insulin doesn't get so hot that it loses efficacy, or freeze if you're on a ski trip. *insulinangel.com*

TAO Wellness Chair
An armchair with built-in strength-training equipment, the TAO Wellness Chair tracks the calories you are burning as you exercise. To strengthen your core, pull or push on the arms to control various games on an attached tablet. You may be seated, but it's far from easy. *taochair.com*

LUMO
Design student Anna Wojdecka invented this hand-held device to help blind people. By shining a light on to any surface it can read what's on it and will turn graphics into vibrations and sounds, in real time. Run the pen-like tool across the page, cross a line and it will vibrate; touch a colour and it will sing – single notes for primary colours and chords for secondary. *hello-lumo.com*

PIP
This handheld biosensor measures your stress levels by monitoring the electrical properties of the skin as you hold it between your thumb and forefinger. The data is sent to an app on your smartphone. Integrated games use your stress levels to control characters; the more you de-stress, the faster they move. *thepip.com*

OTHER EXHIBITORS AT THE CLINIC

MedCity – **Elvie** – Alternative Limb Project – **Carbon Black Wheelchair** – Lumo Lift – **Cupris Health** – The PIP – **Insulin Angel** – Milonizer – **MIRA** – Starstim – **MinION** – Brain Map – **Qardio devices** – TAO WellShell & TAO Chair – **The BRUISE Suit** – MYRUN – **Microsoft Band** – Withings – **LUMO**

THE BUPA STARTUP STAGE ROSTER OF SPEAKERS

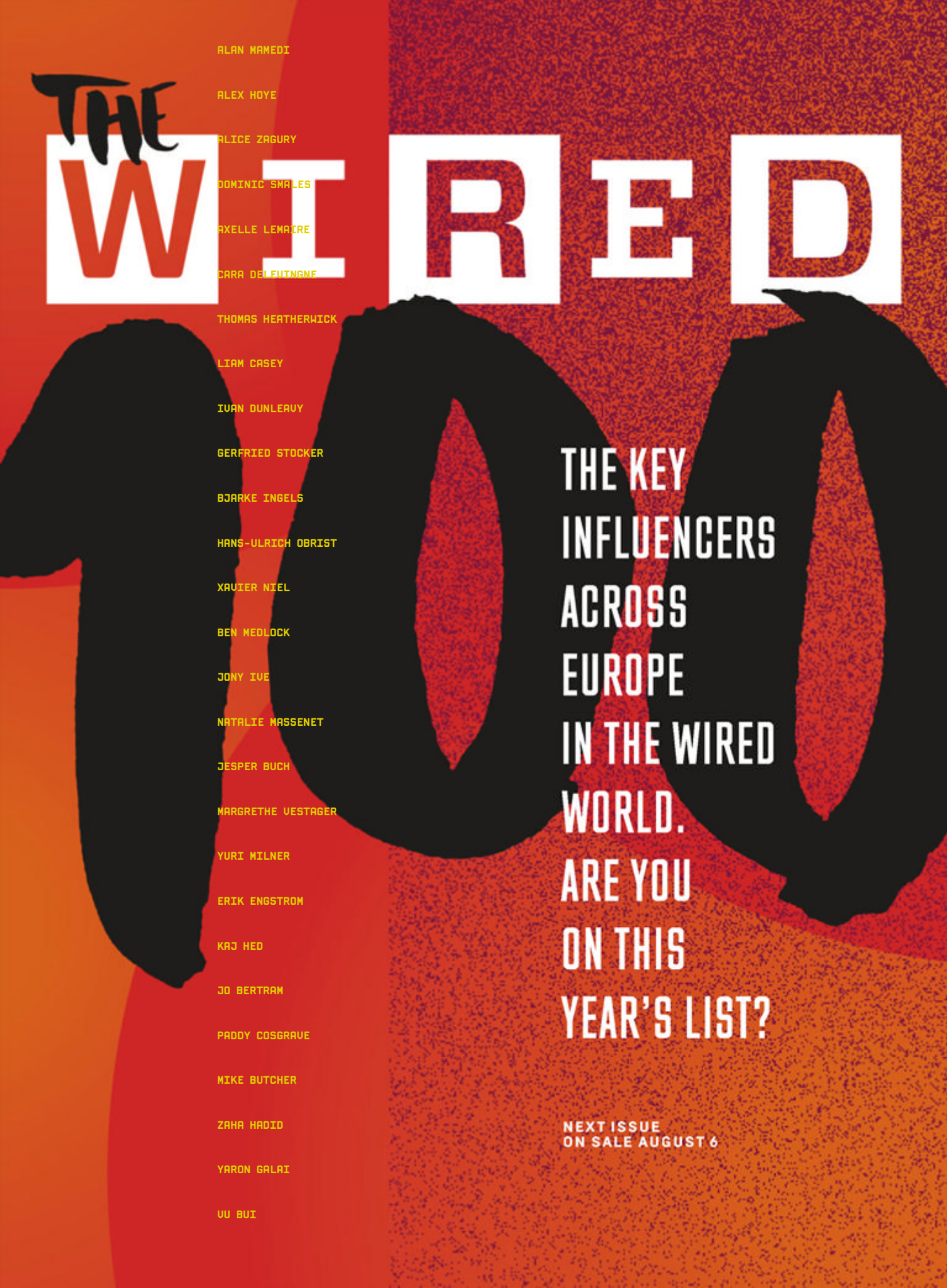
Speakers from 17 health startups presented their visions to an audience of medical experts and high-profile healthcare investors

Jorge Armanet HealthUnlocked
Marcus Foster Klarismo
Elina Berglund NaturalCycles
David Ingram Galvanic Ltd
Johann Huber SOMA Analytics
Rich Khatib Medopad
Ana Maiques Neuroelectrics
Eran Eden MeMed
Kat Cormack Buddy Enterprises
Tania Boler Chiaro
Mike Pallett Cupris Health
Ali Rezaei Haddad GoodSAM
Claire Guest Medical Detection Dogs
Ori Geva MedialCS
Pierre-Emmanuel Meyer MindMaze
Itamar Lesuisse (*below*) Peak
Cosmin Mihaiu MIRA Rehab

WATCH WIRED HEALTH ONLINE

You can see and hear the speakers from the main stage at *wired.co.uk/wired-health-2015*

PHOTOGRAPHY: PETER GUENZEL


THE WIRED
100
ALAN MAMEDI
ALEX HOYE
ALICE ZAGURY
DOMINIC SMALES
AXELLE LEMAIRE
CARA DELEVINGNE
THOMAS HEATHERWICK
LIAM CASEY
IVAN DUNLEAVY
GERFRIED STOCKER
BJARKE INGELS
HANS-ULRICH OBRIST
XAVIER NIEL
BEN MEDLOCK
JONY IVE
NATALIE MASSENET
JESPER BUCH
MARGRETHE VESTAGER
YURI MILNER
ERIK ENGSTROM
KAJ HED
JO BERTRAM
PADDY COSGRAVE
MIKE BUTCHER
ZAHA HADID
YARON GALAI
VU BUI
THE KEY INFLUENCERS ACROSS EUROPE IN THE WIRED WORLD. ARE YOU ON THIS YEAR'S LIST?
NEXT ISSUE
ON SALE AUGUST 6

WIRED

INSIDER

Events, new products and promotions to live the WIRED life

Compiled by Cleo McGee

1 2
3 4

1/Louis Vuitton city travel guides

Louis Vuitton has released a series of beautifully crafted travel books detailing all you need to know when visiting a new metropolis. From Shanghai to New York, there are more than 20 to collect in a range of eye-catching colours. Fill your bookshelf with the full rainbow this summer.
£25
louisvuitton.co.uk

2/Shinola The Runwell bicycle

The Runwell men's bike is a classic blend of urban style and practicality, with a lugged steel frame and forks. A high-end Shimano Alfine 11-speed rear hub means this US-made bike needs minimal upkeep – even after brushes with British rain. It also comes in black, blue and bright red.
£2,530
shinola.co.uk

3/Little Sun solar panel technology

Founded by artist Olafur Eliasson and entrepreneur Frederik Ottesen, Little Sun is a charity project bringing light to people with limited access to electricity. Using solar panels, Little Sun lamps provide ten hours of soft light, or four hours of bright light, from five hours of charging in sunshine.
Buy or contribute at littlesun.com

4/Prada Luna Rossa Sport fragrance

Inspired by the precision and excellence of top-flight sailing, this men's fragrance from Prada is sharp and modern. Created by perfumer Daniela Andrier, its key aroma is lavender, with masculine notes of sage, orange and spearmint cutting through.
50ml £46, 100ml £63
selfridges.com

WIRED INSIDER'S PICK OF UPCOMING EVENTS

WIRED 2015

Our fifth annual two-day event gathers more than 50 speakers, including crossbench peer and entrepreneur Martha Lane Fox, peace process negotiator Frank Pearl, and author Misha Glenny. WIRED will also unveil the 2015 Innovation Fellows.
October 15-16, 2015
wired.co.uk/15

WIRED2015: NEXT GENERATION

This inspirational day is designed for 12- to 18-year-olds. Featuring a range of diverse speakers, plus hands-on workshops, the event is designed to inspire young minds. The 2014 speakers included actor Andy Serkis, BuzzFeed's Ze Frank and music group Rizzle Kicks.
October 17, 2015
wired.co.uk/nextgen

WIRED RETAIL

Now in year two, WIRED Retail 2015 will reveal how technology is turbo-charging this fast-changing sector. The 2014 event saw speakers from Lyst, Farfetch, Etsy and Shutl, and this year's agenda aims to be even more ground-breaking.
November 19, 2015
wired.co.uk/retail

NEXT15 CONFERENCE

NEXT relocates from Berlin to Hamburg and joins with the Reeperbahn Festival – Europe's leading event for music and popular culture. NEXT15 will move away from keynotes and feature more interaction, but you can still expect inspiring, well-respected speakers.
September 24-25, 2015 nextconf.eu

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PHOTOGRAPHY: SUN LEE

PLAY

Unnatural selection

FROM GOAT-GIRAFFES TO SIX-LEGGED CAT-DOGS, ARTIST KATHRYN FLEMING IS DESIGNING A HUMAN-MADE WILDERNESS >

TAXIDERMY MEETS SCIENCE

Natural pecora, such as deer, grow only one type of cranial appendage (antlers). Superbivore grows a blend of all four types

Kathryn Fleming is a human graduate of London's Royal College of Art and the Rhode Island School of Design

The long, giraffe-like neck aids in foraging for food, but is also used in social interactions, such as "necking"

Cloven hooves, such as those found on mountain goats, assist balance on precarious terrain

More than 16,000 animal species are threatened with extinction. What if humans could use biotechnology to help them evolve? Artist Kathryn Fleming (*left*) wants us to imagine just that. "We live in a precarious moment," says Washington DC-based Fleming, 32. "Humans are the greatest influence on the evolution of the natural world."

For her *Endless Form/Endless Species* series, Fleming not only envisions such creatures but creates them, using taxidermy to combine parts of existing animals. "When you start looking at these creatures, you can see they're these perfect designs," she says. "Taxidermy can really help designers to understand natural processes – and then speculate on what might be different."

Among her bio-inspired creations: *artiodactyla optime*, or the "Superbivore" (*pictured*), a future deer whose adaptations include a giraffe-like neck, a 25cm-long prehensile tongue for foraging and cloven hooves that allow it to balance on precarious surfaces. Another beast, *carnivora revibro*, is a part-feline, part-canine carnivore, with fur that can reflect artificial light to dazzle prey. Some features, Fleming says, could be the result of natural selection, others by human genetic intervention. She has also designed a future London Zoo with habitats for each creature.

Fleming is now researching new species at the National Museum of Natural History in Washington DC and has opened a studio, Modern Naturalism, which focuses on applying biological principles to design. "Animals have come up with design solutions that are far outside of what we come up with on our own," she says. "That's what evolution is – hundreds of years of design and development." **OF-W** *modern naturalism.com*

PHOTOGRAPHY: CHARLIE SURBEY. ILLUSTRATION: BEN OLIVER

Sail the cup home

BEN AINSLIE IS AIMING TO BRING THE AMERICA'S CUP BACK TO THE UK

The America's Cup is the world's most-storied yacht race. But despite being founded in 1851 as a race around the Isle of Wight, the 164-year-old event has never been won by a British team. Ben Ainslie is out to change that. An Olympic champion and winner of the 2013 event with Oracle Team USA, Lymington-based Ainslie has launched his own team, Ben Ainslie Racing (BAR), and has set his sights on lifting the title. Key to its chances of success: building a better boat.

From July 23 to July 26, competing teams will set sail in the America's Cup World Series in Portsmouth, host of the preliminary race series for the 35th Cup, which takes place in Bermuda in 2017. For fairness, the World Series will be sailed in identical 13-metre AC45 catamarans, which use hydrofoils to float above the water. But for the America's Cup itself, each team is hard at work building its own 15-metre craft.

"Design and engineering are central to winning," says Ainslie. "These are much more dynamic boats than we have ever seen before, flying on hydrofoils at phenomenal speeds and crewed by great athletes."

"It's much more of a Formula 1 paradigm now," says BAR technical director Andy Claughton of the team's data-led design approach. Among the changes introduced for the 2017 race is a rule that boats must be entirely wind- or person-powered – meaning the slightest edge in aerodynamics or crew performance could be the difference between triumph and disaster. "It's all quite daunting, but I think it will improve the spectacle," he says.

Here, Claughton breaks down the technology and design features that will (hopefully) enable the new boat to sail past the competition this summer. **OF-W** *americascup.com*

1. Hull
The teardrop shape helps the bow resurface quickly if submerged. A GPS beacon lets race organisers track each boat.

2. Sensors
On-board sensors combine data from more than 1,000 measurements – from wave speed to pressure on the sail – in real time.

3. Sail
The 22-metre-tall carbon-fibre wing will be able to generate horizontal force up to three times the actual wind speed.

4. Crew
The six-strong crew train using Oculus Rift and a motion simulator. Sensors embedded in their life vests will record performance data.

5. Hydrofoils
The asymmetrical carbon-fibre daggerboard – the long downwards fins – and rudders act like wings, generating lift.

TEACH CHILDREN PROGRAMMING – VIA DODGEBALL

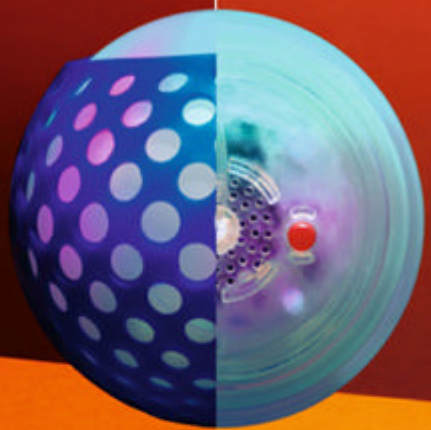
This is the Hackaball: a tough, throwable computer designed by London-based studio Made By Many to help kids invent games – and teach them how to code in the process. "We took one of the oldest play objects and looked how else it could be played with," says the company's founder William Owen, 57.

Youngsters use an iPad app to instruct the Hackaball, made of translucent plastic with a tough silicone skin, to respond to various stimuli. It can also be programmed through an easy-to-use interface. The sensors inside can differentiate between taps, drops, bounces, kicks, shakes and passes. "We'd also like children to be able to record their own sounds – shout a friend's name as the next person to throw it to, for example," says Owen.

The goal, he says, is to introduce kids to programming. "We see the most important use for Hackaball as teaching young children the basic principles of coding through creative play." Young testers built familiar games such as Hot Potato, but also used it to tell stories where it became a shield or a flaming asteroid.

Kickstarter backers have funded Hackaball to the tune of $240,000 (£160,000), with the finished produced expected to ship by Christmas and cost about £75. "The potential is huge," says Owen. "We see the core components that live at the heart of the ball as a platform for a range of future educational products."

Duncan Geere
hackaball.com



The Hackaball contains a gyroscope, accelerometer, speaker, motor and LEDs

Sack the bouncer

BOILER ROOM'S STREAMED DJ SETS BRING LIVE GIGS TO A MILLION FANS AT HOME

Taking nightclubs online might seem counterintuitive, but not for Blaise Bellville. In 2010 the Londoner strapped a webcam to a wall in his Dalston studio to stream live sets by his DJ friends. Today, his startup Boiler Room broadcasts 30 gigs a month to more than a million people around the world – from house in Hackney to LA hip-hop and psych-rock from South Korea. What Boiler Room loses in intimacy, he argues, it more than makes up for in reach. "Suddenly, a kid in Doncaster can access underground grime from London," says Bellville, 30.

Boiler Room has evolved from shows filmed on a laptop and broadcast on Vimeo (because "it was free"), to a bespoke video platform developed by an in-house team that includes hires from Google's Creative Lab. Sets are filmed in HD and edited live for broadcasts that have a fly-on-the-wall quality to them. "The artists don't feel like they're being filmed," says Bellville – vital for performers more used to dingy clubs than primetime TV.

In five years, Boiler Room has gone from a mould-ridden studio ("We had to move out because everyone kept getting these weird coughs") to shows at leading festivals and even a 2,000-year-old Roman amphitheatre. That growth has brought seed funding from Vice Media, a partnership with YouTube to monetise its 600,000-plus subscribers and sponsorship from brands such as Red Bull, Ray-Ban and Adidas.

Boiler Room's next challenge: developing a content suggestion algorithm that challenges viewers' tastes, rather than pandering to them. Bellville says music discovery should be akin to having someone who shares your taste but will also play curveball records you wouldn't pick yourself – he likens it to the type of sets performed by his favourite DJs. "You can't just play the bangers," he insists.

Rather than following up a deep house performance with a second set, its engine analyses the listening habits of a curated set of super-users to serve up anything from South African kwaito to Nordic disco. "It's like when you're in a record shop and something comes on that you listen to in a completely new way," says Bellville. An age-old approach to a modern music. **Tom Banham** *boilerroom.tv*

PHOTOGRAPHY: SAM BARKER, STEPHEN LENTHALL

Blaise Bellville (top) and Boiler Room staff at Corsica Studios, south London

An ultra sharp display

TODAY, ULTRA-HIGH DEFINITION DOESN'T MEAN AN ULTRA-HIGH PRICE TAG – AS POLAROID'S NEW 3D SMART SETS PROVE

Polaroid is back. The iconic visual and imaging brand has released two new TVs that deliver the highest definition pictures, plus an accompanying soundbar for crisp, full audio and a cinema-worthy home-viewing experience.

Featuring 4K ultra-high-definition resolution – that's an incredible four times the detail of 1080p – both the 55-inch and 65-inch versions of the Smart 3D LED TVs offer some of the highest specifications available at home.

To make the most of the 3D capabilities, both sets ship with eight pairs of 3D glasses, so no one misses out on the experience.

You won't miss your favourite show, either. The built-in Freeview HD features up to 12 digital HD channels, plus more than 60 regular Freeview channels. And the Polaroid smart portal gives access to catch-up TV services, movie streaming and social media.

The slim, light TVs can be wall-mounted, and look as sharp as their images do. In addition, the 55-inch version topped a *What Hi-Fi?* 4K TV group test, gaining four stars in the process. So, all in all, it's a smart package.

Only at Asda, £699 & £1,099

The TVs boast Wi-Fi, four HDMI inputs and four USB inputs

Hear the difference

60-Watt Soundbar
This slim soundbar brings your audio to life with a rich, sharp sound coupled with wireless connectivity (*£69*).

Remote control
A neat and tidy remote allows you to control the Polaroid soundbar from the comfort of your sofa.

Subwoofer
The soundbar ships with a subwoofer, enhancing bass and bringing an extra dimension to music and movies.

Pixar's Mr Emotional

PETE DOCTER IS READY TO TUG ON YOUR HEARTSTRINGS AGAIN WITH INSIDE OUT

Pete Docter: "I didn't understand what the rules were at school"

This man is Pixar's secret weapon. Pete Docter joined the animation studio straight after graduating from university in 1990. Having helped develop *Toy Story*, he went on to co-write *WALL·E*, direct *Monsters, Inc* and *Up* (for which he won an Oscar) and has spent the last six years making *Inside Out*, released on July 24. Set inside the mind of 12-year-old Riley, it shows what's happening – chemically – through the perspective of her emotions (including joy, anger, fear) as she hits adolescence. Pixar tackles feelings, dreams and memories as uniquely as you'd hope: it's fun, inventive and surprisingly intense. WIRED met Docter in California to talk about the research behind it, designing the characters and why it's his most personal film yet. Alex Godfrey

WIRED: *Inside Out* isn't like anything you've done before. How confident were you that you could make a film about emotions?

Pete Docter: I think I was delusionally confident. I didn't know how difficult it was going to be to make it all connect. Even design-wise, making these characters look like the emotion they were supposed to represent turned out to be really hard.

You were inspired by seeing your daughter hit adolescence and become withdrawn. When did you start thinking about it as a film?

Pretty early on. And, early on at Pixar we look at these as little therapy sessions, where we talk about what the idea means to us and how we could use it for storytelling, to relate to people. For myself, junior high school was a really dark place.

You had a rough time?

I did. I felt very out of step and didn't understand what the rules were. Looking back, I don't think I really

PHOTOGRAPHY: RICHY MIDDLESWORTH

'THE SUBJECT MATTER I'M DEALING WITH IN THIS MOVIE IS THE KEY TO RELATIONSHIPS'

Mind map: Joy and Sadness journey through the mind's corners – Imagination, Dream Production, Abstract Thought and the Subconscious

had any friends, I didn't know how to connect and reach out to people. So when I saw my daughter starting that way, I was like, "Oh, she's got my genes... she could go through that same thing. That sucks."

How did you go about designing the film's characters?
We wanted the characters to look the same way emotions feel. We did some early experiments, making them appear vaporous and ghostlike, but they looked too much like ghosts. So we came up with these bubbly little things, it kind of feels like soda-pop fizz, or atoms – a nucleus, electrons roiling around.

You worked with psychologist Paul Ekman. What was his input?
He had done a notation system [in 1978]: the Facial Action Coding System. What that meant was he could look at the expression a person is making and say, "It's a 14+12, because you're raising this eyebrow a little bit and you've got a little sub-orbital muscle there." That was fascinating to me as an animator because that's the kind of language we deal with. We also worked with [psychology professor at University of California, Berkeley] Dacher Keltner about understanding what makes people happy. The things we think will make us happy like wealth and whatever are usually not at all the true things that bring you deeper happiness.

Science suggests that what really makes a person happy is a good relationship...
I'll tell you a story: there was a dark point about three years into the making of the film. The pressure was mounting. We were approaching a screening and I went for a walk the weekend before, going, "Shoot, it's just not working. What if I just quit and move to Mexico – what would I miss the most?" And I thought, well, my friends. But then I thought, the people I really feel close to are the people that, yeah, I've felt happiness with, but also they are people that I've been pissed off with, and scared for. The subject matter I'm dealing with in this movie is the key to relationships. So I got electrified, rewrote the script and that was a major turning point.

Having an epiphany after hitting rock bottom. Have you ever had that before while working on a film?
I have, on almost every film. [Laughs]

You researched memories and dreams as well – what particularly surprised you?
With memories, certain people are trying to get eye-witness accounts thrown out of court cases because it's notoriously unreliable. What you feel convinced of, like, "I know this happened" is as likely as not partly a to be a product of your own imagination. Every time you recall something, the way the mind works is it diffuses the original and re-encodes it, so it's like a Xerox of a Xerox. There's dissension among scientists as to the purpose of dreams. You talk to Freudian analysts and they're talking about working out issues, and neurologists say it's just the random firing of neurons. But who knows exactly? In that case we just went for entertainment.

Has working on *Inside Out* made you more aware of how you think and feel in real life?
At times. Since the film I've definitely become more aware and I feel like it's changed the way I think. Paul Ekman pointed out that the whole system of our mind is designed to keep us unaware of what's going on subterraneously. I think it's made me more understanding of other people – my daughter, myself and relationships.
movies.disney.com/inside-out

HOW PIXAR PLAYS WITH YOUR EMOTIONS

WALL·E
Docter's Oscar-nominated script showed that robots need love too.

Monsters, Inc.
Also up for an Oscar, this taught kids the power of laughter over fear.

Up
Showed an entire lifetime in one devastating three-minute sequence.

Digital extra!
Download the WIRED app to read more on the making of *Inside Out*

OCEAN

OCEAN LABS

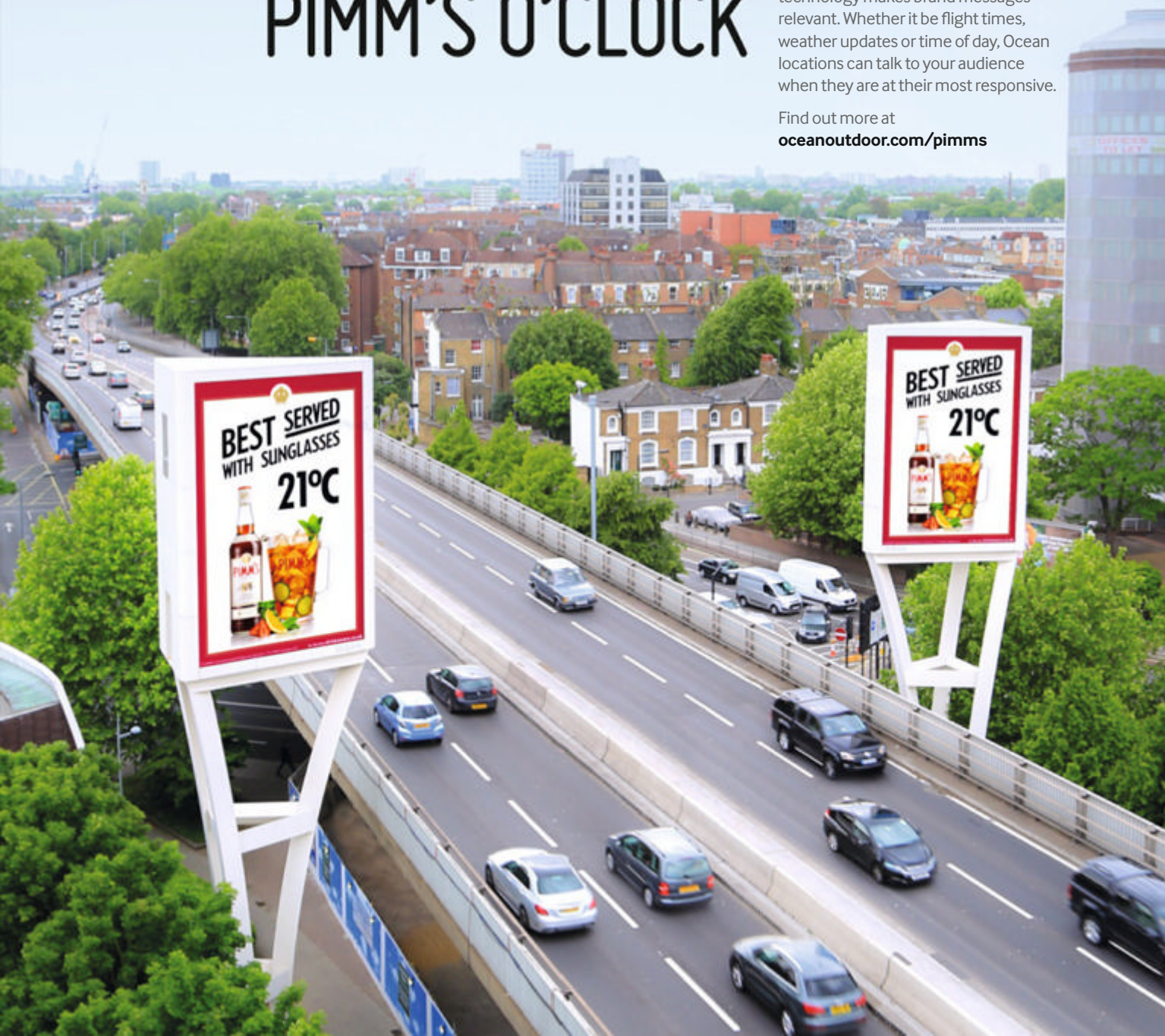
DIGITAL OUT OF HOME TECHNOLOGY SERVES THE PERFECT PIMM'S O'CLOCK

Pimm's, the classic drink of the Great British Summer, launched an exclusive thermal activation campaign on Ocean's digital out of home locations.

Using a live data feed generated by Liveposter, the campaign, planned by Carat and Posterscope was activated across a combination of screens every time the weather reached a summery 21°C.

Data driven digital out of home technology makes brand messages relevant. Whether it be flight times, weather updates or time of day, Ocean locations can talk to your audience when they are at their most responsive.

Find out more at
oceanoutdoor.com/pimms

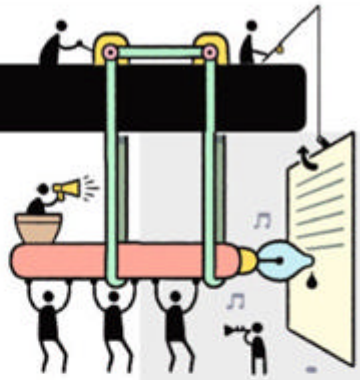


Dyed in the wood

DESIGN DUO RAW-EDGES BOILS UP A WAY TO COLOUR TIMBER

Shay Alkalay (*above left*) and Yael Mer (*right*) have invented a way to dye wood permanently. "We get curious about a process and then experiment with it," says Alkalay, one half of the Israeli husband-wife collaboration that makes up the Raw-Edges studio. Their new furniture collection, Endgrain, was the result of one such experiment. "We designed the floors of 40 Stella McCartney stores around the world with coloured parquet wood flooring, but wherever there was a lot of foot traffic, the colour would fade," says Alkalay, 39. "We thought there must be a way to inject the dye into the timber, so no matter how much traffic it has, it holds the colour inside." They boiled wood with a dye in huge vats, just as silk is dyed to make Persian rugs. "Cedar wouldn't soak up anything, no matter how long we cooked it and at what temperatures and pressure," he says. Eventually they hit upon two – southern yellow pine and jelutong – which they boiled for three days and then cooled. The woods were absorbing dye along their end grain – the cross section, rather than along their length. "There seems to be a pressure element during the cool-down which helps to soak dye into the grain." They then milled the wood with CNC machines and patterned shapes across it at a 45° angle.

The couple will be creating pieces from the collection for the new Design Museum, which opens in London's Holland Park next year. "Wood suppliers told us we should keep it away from moisture, because any humidity would destroy the wood – but we soaked it for days in boiling water," says Alkalay. "We went against anything experts told us to do." **Madhumita Venkataramanan** *raw-edges.com*



THE WRITER USING THE CROWD AS CO-AUTHOR

A book is a finished product – or is it? British poet Martin Jackson, 33, is writing his novel *TBC*, live on Google Docs. (The name, like the content, will be decided by the crowd.) *TBC*'s plot centres on a drone attack on Whitehall. But although Jackson has a skeleton of a storyline, the reader is invited to comment, research – and contribute.

According to Jackson, the aim is to make editing a collaborative effort. He's previously played with Google: in 2014 he declared himself "writer in residence" of Google Maps, publishing a series of poems exploring the app's social politics. Twitch streaming, Jackson believes, may signal the end of an era for reclusive authors.

"The encasing of a 'finished' text within the hermetic seals of covers has to end – or at least be seriously messed around with" for literature to stay relevant, Jackson says. The crowd is coming: WIRED editors, look busy! **Lucy Smith** *goo.gl/yQh6sF*

PHOTOGRAPHY: JAY BROOKS. ILLUSTRATION: GIACOMO GAMBINERI

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300 DECORATIVE PANELS UP IN SMOKE

Temple of boom

ARTICHOKE BUILDS ART ON A MASSIVE SCALE – AND HELPS TO HEAL DIVIDES IN THE PROCESS

Helen Marriage wants artists to think a little bigger. Her London-based arts non-profit Artichoke produces exhibitions on an epic scale: taking over cities, not galleries. Take *Temple* (*pictured*), by American artist David Best. Built in Londonderry in March, the 22-metre-tall plywood structure was constructed in six weeks: volunteers were trained to turn Best's sketches into CAD models and a team of unemployed carpenters worked on the construction. "It's like a puzzle – we start picking up the pieces and putting them all together," Best tells WIRED.

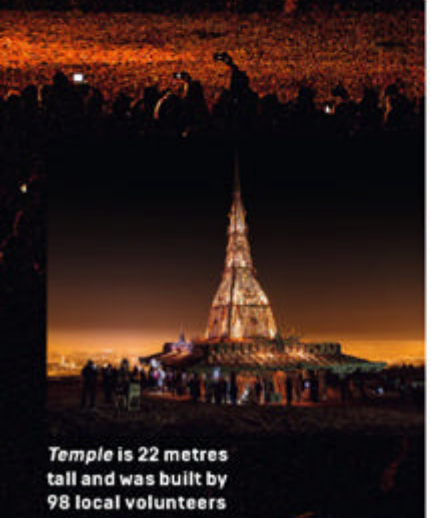
Like the eight towers that Best has built for the Burning Man festival in Nevada's Black Rock Desert, the plywood structure was set alight on March 21 after being filled with messages for loved ones by visitors from both sides of Northern Ireland's religious divide. "You're making a building for people who have lost their sons and daughters, so the aesthetic can look delicate and gentle, but the building itself must be strong," says Best. "The Catholics and Protestants burned bonfires with effigies of people they hated from the other side," adds Marriage, "so we wanted to do something that was more

about a universal reconciliation of peace."

Artichoke's first event in 2006, *The Sultan's Elephant*, closed streets in central London for three days, as a 12-metre-tall mechanical pachyderm and a six-metre-tall girl were seen by millions as they wandered along The Mall. "Our target audience is people who wouldn't go to see a play or visit a gallery," says Marriage. "We're always interested in being in the public domain, making stuff accessible and putting the imagination of extraordinary artists in front of an audience who would never buy a ticket."

The company's next project is its biennial Lumiere event in November, when Durham will be filled with light installations. "We work with 30 artists and they build things all over the city," says Marriage. "It can be anything, from free-standing sculptures to interactive digital work, neon signage, fire and flame." The one guarantee: you won't be able to miss them. **Sophia Epstein**
artichoke.uk.com

PHOTOGRAPHY: MARK NIXON



Temple **is 22 metres tall and was built by 98 local volunteers**

Winchester-based artist Olly Moss has built a devoted following for his smart, stylised posters for pop-culture phenomena, from *Star Wars* to Marvel-commissioned artwork for *Thor* to the cover of the video game *Resistance 3*. So when Sean Vanaman and Jake Rodkin, two of the creative leads on Telltale Games' award-winning *The Walking Dead*, decided to found a new games studio, they turned to Moss with an idea. "Before it was always, 'Would you like to do packaging design, or T-shirts?'," says Moss, 28. "Which is flattering, but I wanted to get my hands dirty."

Together, the three of them founded the studio Campo Santo. In their first title, *Firewatch*, out in August, players take on the role of Henry, a fire warden in the wilds of Wyoming's National Park. With no company but a radio link to his supervisor, Henry finds mysterious happenings drawing him from the safety of his watchtower. To create the game's stunning environments, Moss's original sketches were turned into a 3D world by Campo Santo's designers. After an initial "paintover" – changing objects in the level to increase their visual impact – Moss then adjusted details (*his instructions to the designers are below*) such as fog, colour and lighting to bring it closer to his vision, both within the game's engine and using more traditional tools. "It's like grading a film – you can export screenshots to Photoshop, tweak the colours and export it back into the game." The result: less a game, more a playable, explorable Moss artwork.

Olly Moss found inspiration in US National Park posters of the 60s

Although most of the action in *Firewatch* takes place in the great outdoors, Henry's cluttered watch station gave Moss a chance to put his graphic design skills to bear on everything from book covers to cereal packets. "Every time I get bored with drawing rocks and trees I go, 'Fuck it, I'm going to make a book cover,'" says Moss. "It's like having dessert after a meal of trees, rocks and sky." **Daniel Nye Griffiths**
Firewatch *is out this summer for PC, Mac and Linux firewatchgame.com*

PARKS RECREATED

Back to the dystopian future

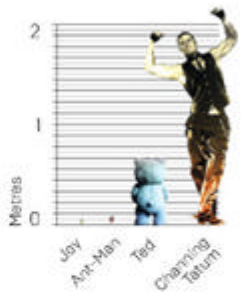
Ernest Cline is mortified. In 2011 he wrote his debut novel, *Ready Player One*, a pop-culture-drenched dystopia about virtual reality, which became a *New York Times* bestseller. Then, in March, Steven Spielberg signed on to direct a film adaptation. The awkward part? Cline's book makes fun of the director's work. "A character refers to *Indiana Jones* as one of the holy trilogies and then he clarifies that by saying he doesn't recognise [the franchise's less than stellar fourth film] *The Kingdom of the Crystal Skull*," recalls Austin-based Cline, 43 (*pictured*). "I never imagined in a million years Spielberg would read it!"

Ready Player One's runaway success made Cline's second novel *Armada*, a daunting task. "I'd joke that it was called *Sophomore Slump*, with *A Lacklustre Follow-up* as its subtitle." The book's plot centres on small-town schoolboy, Zack Lightman, who discovers that his favourite video game is in fact a secret government initiative to train pilots for fighting off an impending alien invasion. The premise was inspired by Cline's own childhood desire for adventure. "I grew up in rural Ohio," recalls Cline. "Arcade games were like portals into different worlds."

When *Ready Player One* came out, some criticised its nostalgia – yet it also anticipated the impending wave of virtual-reality technology. "It makes me feel like Arthur C Clarke predicting satellites," he says. (Employees at Oculus Rift are told to read Cline's debut; the company even named a meeting room after the book's virtual world.) "The fact that Spielberg is making the film is going to change the course of virtual reality and how quickly it gets adopted, as so many people see what he does."

So how is he going to handle the *Crystal Skull* situation when he meets the director? "I'll claim separation from the character," he says. "I still might get banished – we'll see."

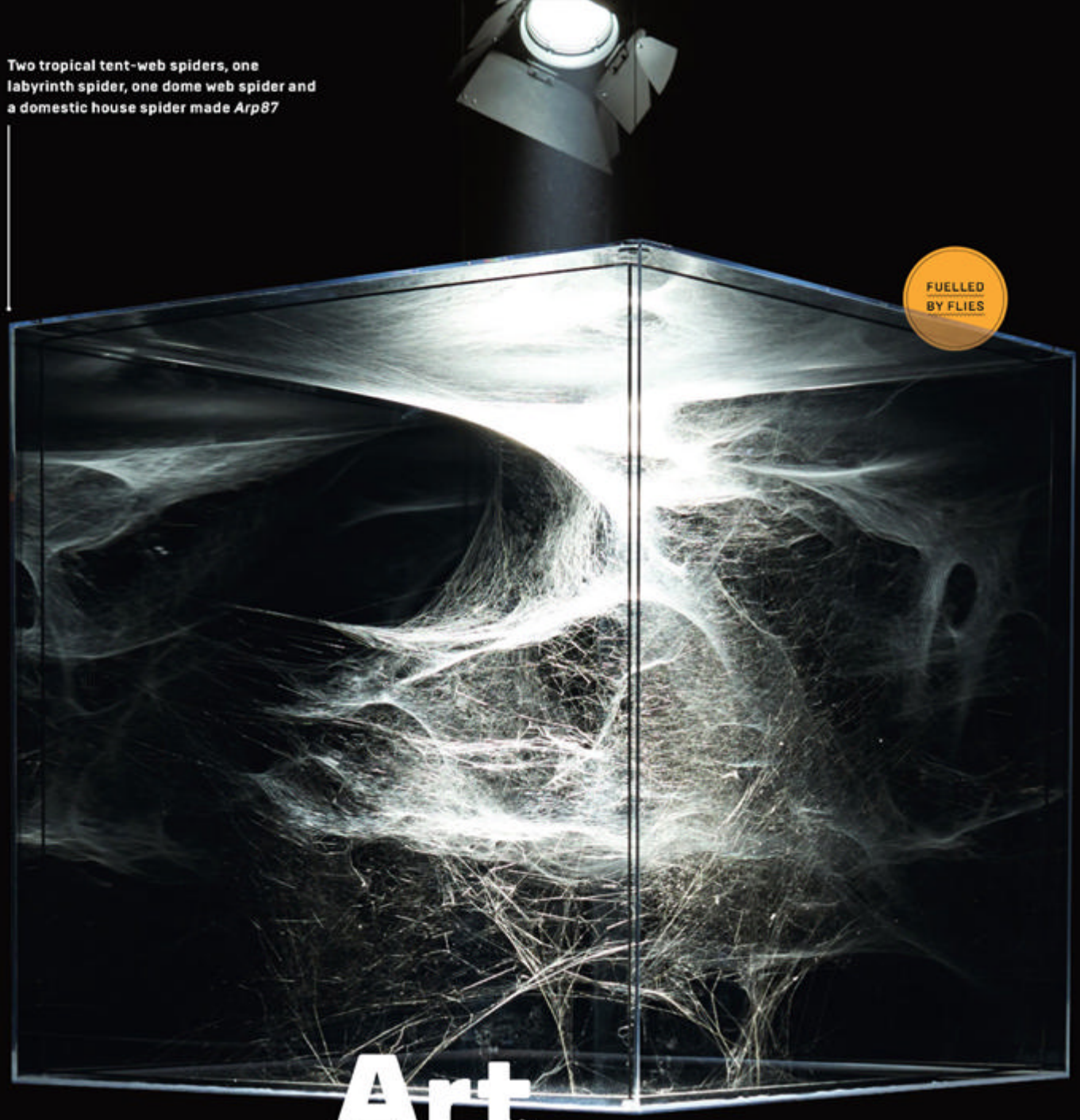
Charlie Burton Armada *is out on July 16*



CHARTED

SIZE DOES MATTER

This month's movies are obsessed with height, from the tiny (*Ant-Man*) to the overcompensating (*Magic Mike XXL*). How do they measure up?



Two tropical tent-web spiders, one labyrinth spider, one dome web spider and a domestic house spider made *Arp87*

FUELLED BY FLIES

PHOTOGRAPHY: DAN WINTERS; BRETT MOEN

Art on the web

SPIDERS STEAL THE SHOW IN TOMÁS SARACENO'S INSTALLATIONS

Tomás Saraceno loves cobwebs. The Berlin-based architect turned artist builds installations inspired by intricately woven spider silk. Take his current project in development, which he will show in Germany at the end of this year. "Imagine a huge web that people can play with their bodies," says the 41-year-old Argentinian.

For his recent *Hybrid Solitary... Semi-Social Quintet... On Cosmic Webs* series, Saraceno collaborated with the spiders themselves. "I experimented with different breeds weaving webs together," he says. For each sculpture, a solitary spider was placed inside a Plexiglas box or on to a frame, where it would begin to spin its web. The largest piece, constructed by two spiders, a colony and a solitary giant house spider, took 18 months to complete.

He also rotates the boxes to change the critters' sense of gravity. "It's to rehearse for the weightless environment," he says, "We are going to send spiders to the International Space Station where they will try to weave. We're going to turn them into spidernauts." Watch out, Spidey – there's a new web-slinger in town...

SE *tomassaraceno.com*

Playlist

▼DAMN FINE COFFEE
Surprisingly, this isn't an art project by the cult director and musician (or is it?). But, given *Twin Peaks*' obsession with coffee, it was only a matter of time. Best drunk black as midnight on a moonless night... *davidlynchcoffee.co.uk*

▲AUDIBLE ART
In *Soundscapes*, six musicians, including Jamie xx and Susan Philipsz, have composed a piece based on an artwork in the National Gallery, which will rehang it in a dedicated room with its accompanying music. *From July 8 nationalgallery.org.uk*

◀BABY TROUBLES
Amazon's space-pregnancy drama *Extant* returns, with Molly (Halle Berry) back on Earth and now trying to track down her alien progeny to stop them threatening the entire planet. Space kids, eh – who'd have them? *From July 2 amazon.co.uk*

◀HIGH-VIS, MEET HIGH FASHION
Madison Maxey uses UV-reactive ink to create clothes that change in sunlight. The garments' appearing and disappearing geometric patterns are inspired by complex parametric equations and scientific concepts. *madisonmaxey.com*

▼OLD-SCHOOL ADVENTURE
California developer Playdek wants to bring back the tactical RPG. *Unsung Story*, which raised $600,000 on Kickstarter, is a beautiful medieval adventure co-designed with *Final Fantasy XII*'s Yasumi Matsuno. *unsungstory.com*

▶FABRIC IN BLOOM
Rotterdam-based design studio Wandschappen shapes felt wool into ultra-detailed botanical sculptures. Not only do you not have to water them, they're designed to act as sound dampeners to improve office acoustics. *laive.nl*

PHOTOGRAPHY: SPENCER KOHN; THEO VAN PINXTEREN; THE NATIONAL GALLERY, LONDON

James Anderson

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HOW TO

ILLUSTRATION: CRIOL VIDAL

How to...

Conquer rejection

Suffering rejection can be really tough – but Jia Jiang, the author of *Rejection Proof: How I Beat Fear and Became Invincible* (Random House Business), knows how to turn it to your advantage >

After failing to procure seed investment for his startup, San Francisco-based Jiang challenged himself to go through "100 days of rejection", and then blogged about it. "At the beginning, I was just trying to overcome fear," he says. "But I learned so much by getting in front of people and talking to them." The blog morphed into the book. "I thought it would be helpful to know what rejection is; how to overcome it and turn it into opportunities." Here's how you can become invincible, the Jiang way. Emiko Jozuka

1. UNDERSTAND REJECTION

"We often think that rejection is some sort of obstacle, a painful event that we have to overcome," explains Jiang. "But I found that rejection is very subjective. It's nothing more than someone's preferences and opinions." In his assertion that there's no such thing as a "universal acceptance or rejection", Jiang states: "If you want to get a 'yes' from someone, you sometimes just have to talk to a lot of people. Some of the best books, ideas and products have gone through rejections first."

2. POSITION YOURSELF

It's important to be able to maximise your chances of receiving a "yes" from someone. Honesty and a direct reference to a weakness in your request increase your chances of an affirmative response, says Jiang. Instead of going straight for the kill, Jiang recommends you empathise with people before asking for something. Do this by either acknowledging that your request may be strange, or that you're aware you're asking for a big favour. "Make these qualifiers to let people know that you understand that what you're asking might be difficult," advises Jiang.

3. GET PAST 'NO'

If you're refused something, Jiang recommends you always ask why. The psychological pain caused by rejection makes people more likely to end conversations soon after a "no" is issued. But, when faced with rejection, you should stand your ground. "The best thing to do is stay engaged in the conversation," says Jiang. Asking for justification for someone else's decision gives you time to think, and to learn the reasons behind a "no". Jiang recommends you turn your rejector into a collaborator as this vanquishes any adversarial feelings. "If you ask why it was rejected, you then become collaborators – two people on the same side trying to solve one problem."

4. LEAVE YOUR COMFORT ZONE

In any situation, self-rejection is the enemy. "We anticipate rejection, but a consequence of that is that we become our own rejectors. The worst that can happen is not that people say 'no' to you, it's that you say no to yourself," says Jiang. To resolve this, he recommends you challenge yourself. "Your comfort zone is like a muscle. The more you exercise it, the more confident you'll be." He recommends you do this gradually. "By leaving your comfort zone, you get stronger until something that you once thought was risky, is now part of your comfort zone."

5. SHARE YOUR FAILURES

Instead of fearing rejection, we should let the world witness us fail now and then. "Most people are afraid of rejection," Jiang says. "But if you have a problem you need to solve, open up and don't keep it to yourself." Jiang debunks the concept of having to appear perpetually strong and says that if you admit faults, someone out there will empathise. "If we own up to our fears publicly, we will become leaders in the tribe fighting against whatever it is that we're fighting, because then you're inspiring others."

How to...

MASTER SOUS VIDE

The art of sous vide – vacuum-packing food then slow-cooking it at a low temperature for optimum results – has been used in restaurants for decades. Sarah James, editor of sousvidely.com, tells us how to get the most from this culinary technique. **Rachel Walker**

1. BUILD A WATER BATH

The first step is to find a container suitable for cooking boil-in-a-bag style. James recommends starting off by souping up a stockpot. This works for steaks or fillets of fish, but when you're ready to graduate to a rack of ribs or whole chicken, you'll need something bigger. Once James outgrew her stockpot, the next stop was a transparent polycarbonate box. Polycarbonate

has the added advantages of retaining heat and withstanding high temperatures – and the boxes come in all shapes or sizes. Go for a 25-litre box if you have something ambitious in mind (Heston Blumenthal cooked a pig sous vide).

2. REGULATE THE WATER

You can maintain the cooking water temperature for a couple of hours or more using an immersion circulator, which heats and regulates, but it is expensive. Food that doesn't need cooking for long periods can be done in a big sink. The inside of a salmon fillet needs to reach only 48°C, which can take just 20 minutes. And if a big sink is filled with hot water around 50-52°C it will hold that temperature for

ILLUSTRATION: ORIOL VIDAL; TOM FROSE; TONI HALONEN

How to...

Upload a YouTube film in 3D

Three-dimensional video has been around in one form or another since the early 1900s, and was popularised in the 50s using anaglyph glasses (one lens blue, one red). Video-production equipment during this time made amateur 3D movies cost-prohibitive, but with cheap video cameras now widely available, home 3D recording is well within reach. Jeremy Cook

WHAT YOU WILL NEED

Engineering graduate Francesco Fagnoni made a 3D set-up while at school. You need: two identical cameras; a piece of wood 10cm x 5cm x 6mm; two identical screws as a tripod and 6mm longer than the wood (¼ – 20 threads will work for most cameras); a computer to produce videos; 3D anaglyph glasses.

1. CONSTRUCT YOUR 3D RIG

Drill two holes for your screws, 6.5cm apart. Place the cameras side-by-side on the outer holes and screw them in so they point in the same direction. Washers can be used if the screws are too long for the holes. In order to start the cameras at the same time, it's helpful if your cameras have remote control.

2. GET FILMING

Find a good place to set your 3D rig and focus on something. If you have to start the cameras manually, the videos will need to be synced in post-processing. Subjects in the distance will not be as interesting in 3D, since the change in position will be less noticeable. Try to focus on people or objects that are close.

3. TRANSFORM IT INTO 3D

Transfer the left and right video into separate folders on your computer. Download a 3D tool such as Stereoscopic Player. Once launched, click "Open left and right file": you will see your video displayed in 3D. If the images are not aligned, press CTRL and the up or down arrow to adjust.

4. PRODUCE AND SHARE

In order to upload videos in 3D, Fagnoni uses StereoMovie Maker, but other software is available. Using this program, you can open the sources, adjust and synchronise as needed, then produce the video in "side-by-side" mode, which can be uploaded to YouTube. Add the tag "yt3d:enable=true" to tell YouTube that it's a 3D video. Once the video is playing, click on the gear icon, then select "3D options", to select the type of 3D glasses that you will use with the video (coloured-lens, interleaved, HTML5 stereo, etc). YouTube will then format it.

half an hour. James says a cool box is another good receptacle: "Just heat up the water a few degrees hotter than you want – because it will cool when you add the food," she says. "Fish, steak, chicken and chops all work well with this method."

3. OUT OF THE VACUUM

Professional kitchens use embossed bags and vacuum sealers to pack their food before immersing it. "Water conducts heat 20 times more efficiently than air," James says, explaining why it's important to squeeze out all or as much air as possible. "If you have pockets of low-temperature air surrounding your meat and are cooking at a low temperature it can be dangerous." To avoid this,

simply place the steak, fillet or vegetables in an unsealed freezer bag and lower into the water bath. "All the air gets forced out," says James. Seal it slowly while it's mainly submerged, and you're ready to go.

4. CHECK THE TEMPERATURE

Culinary probe thermometers cost a few pounds but are important. They allow the cook to check the temperature of the middle of the fish or meat before serving, to ensure it has reached a safe temperature. A well-done steak, for example, should come up to 70ºC. Those who like their steak rare, however, should stop it cooking once the centre reaches 54ºC – any lower and the temperature could veer from being

hot enough to cook the meat, to being in the "danger zone" where bacteria multiply. Different foods have different base temperatures. The centre of chicken must reach 60ºC, the centre of fish 40ºC. Consult a guide, like the one at chefsteps.com.

5. DON'T BE AFRAID TO GO BIG

"Most people start off with eggs, but for me it was steak, steak and more steak," says James. (The advantage of sous vide eggs is that they don't need vacuum bags – they cook in their shells.) If an egg doesn't seem worth the effort, start with hulking chunks of meat: "Fancy restaurants have been cooking steaks sous vide since the 70s," says James. "It's easy to create the perfect medium-

rare steak with practically zero effort. Just season your steak, bag it, cook at 55ºC for an hour, sear it in foaming butter in a hot pan and you've got something which is top-restaurant quality."

How to...

Make a box for your car subwoofer

So your car's puny stereo isn't living up to its neighbourhood-shaking potential? Just add a subwoofer. You'll also need a box to mount it in, which can, of course, be bought, but why not build one? Maker Jonathan Neumann created a setup that "hit hard, had great mid- and low-range notes but kept the music clean". Here's how you can reclaim your street cred. JC

1. Plan your build

For his build, Neumann needed to fit a 31cm speaker, which the manufacturer said should be in a 21,000cm³ to 35,000cm³ enclosure. His recommendation is to design a box that will fit your speaker and trunk, at least 5cm deeper than your subwoofer. Multiply length x height x depth of the box's interior (subtract twice the width of your materials) to obtain your specs.

2. Acquire the parts

For your custom speaker box, you'll need a subwoofer and 20mm MDF (cut with a table or circular saw, or have the DIY shop cut it). You'll also need a drill, pencil, tape measure, ruler, jigsaw, string and box cutter. Obtain 40mm-long wood screws, caulk, carpet and spray adhesive. A speaker terminal cup, as well as 12-16-gauge speaker wire, is also needed.

3. Cut your MDF

Cut the front piece of MDF that will hold your speaker, as well as the back MDF section into the full height of your design, and the width of your design minus twice the material thickness (40mm). The top and bottom will be the same length as the front section in one direction by the depth dimension minus twice the thickness (40mm) in the other. Also cut two side pieces.

4. Attach the box

Drill two sets of pilot holes on each section, evenly spaced 10mm from the edges. Do the same for the sides, and drill four evenly spaced holes on each long edge, and one or two extra holes on the short edges. Place the front section on the top and bottom pieces aligned with the holes and secure with wood screws using the pilot drill. Repeat for the back.

5. Add the finishing touches

Apply caulk to the inside edges of the box to form a good seal and let it dry. Apply spray adhesive and cover with carpet. Cut the final side with a box cutter, letting the edges meet as seamlessly as possible. Cut out material for the side pieces and apply in a similar manner. Cut off excess material, as well as the holes for your speaker and the terminal cup.

6. Fit your subwoofer

Centre your terminal cup and secure with screws, drilling pilot holes as appropriate. Attach wires from your subwoofer to the terminal cap. Lower the subwoofer into the large hole and mount with wood screws. Tighten in a star pattern like a car's wheel, making sure not to let the driver slip off and penetrate the surround or cone of your speaker.

How to...

CREATE PETRI-DISH FX

Special FX artist Joe Schenkenberg specialises in using household objects to create high wow-factor visuals, such as warp-speed patterns with steel wool. He shares tips via a YouTube series, Shanks FX. Here's his "atmospheric worlds in a Petri dish". Kathryn Nave

What you need

- Milk
- Food colouring
- Petri dish
- Two pocket lights
- Washing-up liquid
- C-stand
- Camera

Set up

Use a C-stand to clamp the camera over the Petri dish. "Point one light underneath the dish," Schenkenberg says. "Then place another light to the side to give an atmospheric ring around the edge of the dish."

Choose your milk

Different milks produce different effects. "The fattier it is, the slower the reaction," Schenkenberg says. "When you want something to look larger, you want things to move slowly." He uses semi-skimmed milk.

Add food colouring and washing-up liquid

Fill the Petri dish with a layer of milk, then use a dropper to add the colouring around the edge. Add the washing-up liquid and the fat molecules will push apart, moving the colouring around the dish.

Enhance in post

"In post-production I added just a hint of 3D light and also added some edge-glow to give the direction of the Sun, as if it was casting light on the planet," Schenkenberg says.

How to...

Make a Millennium Falcon quadcopter

Any *Star Wars* fan worth their salt will recognise the iconic shape of the *Millennium Falcon*. Olivier Chapuis, a CAD designer from Grenoble, France, took his fandom to the next level: he attached a *Falcon* shell to a quadcopter drone to make a flying replica of Han Solo's light freighter. Follow these steps to make your own fastest hunk of junk in the galaxy. JC

ILLUSTRATION: LAUREN ROLWING
RYO TAKEMASA, GABRIEL SILVEIRA

Gather your kit

You'll need a razor knife, scissors, tape, sandpaper and a hot-glue gun. Extruded polystyrene insulation of 20mm and 30mm thickness and grey paint will be needed for the body. Use a computer with a printer to produce a template, and a compass (or string and two pencils) is needed to transfer several circles on to the insulation. Two LED clusters will go in the front of the craft, and one blue and one white LED strip will go on the back to simulate the main thruster. Chapuis used a quadcopter with 335mm between the four rotors, but the design can be scaled up or down, depending on your rig.

1. Print the pattern

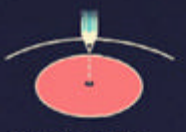
Find or draw a top-down view of the *Falcon* on your computer (excluding the rear thruster overhang). Scale as necessary to fit the four rotors inside, and print the template out, using more than one sheet if necessary.

2. Cut the outline

Draw four circles slightly larger than the quadcopter rotors and the same pattern inside the *Falcon*'s main body circle. Place a dot in the centre of each. Cut out the excess paper, leaving only the ship's outline. Try to keep the centre of mass in the middle of your ship as you construct the foam disguise.

3. Keep cutting

Tape the template to your 30mm insulation. Cut around the outside with the razor knife to form a rough *Falcon* shape (including, importantly, the distinctive side-mounted cockpit).



4. Make a circle

Pierce the circle through the centre mark for each rotor, leaving an impression on the insulation. Then remove the template.

5. Add insulation

Use a compass, or pencil-and-string arrangement, to create propeller circles around these four centre marks, then cut them out. Cut out a long piece of 30mm insulation, about 50mm high at its apex to form the top. Glue it longways to the top from the back of the ship's hull to the fork in the front mandible.

6. Finesse shape

Construct some hardware out of the insulation to attach the quadcopter to its new shell. Hot glue it to the bottom of your *Falcon*. On the top, glue a centre circle as well as horizontal members made out of the thinner insulation, branching out forwards and to the sides in order to further imitate the "real" spaceship.

7. Finesse further

Cut out two circles roughly the same diameter as the side members. Glue them to the side notches to form the escape pods, removing insulation as needed. Add insulation on the cockpit section, then remove the material to form a spherical shape.

8. Install thruster

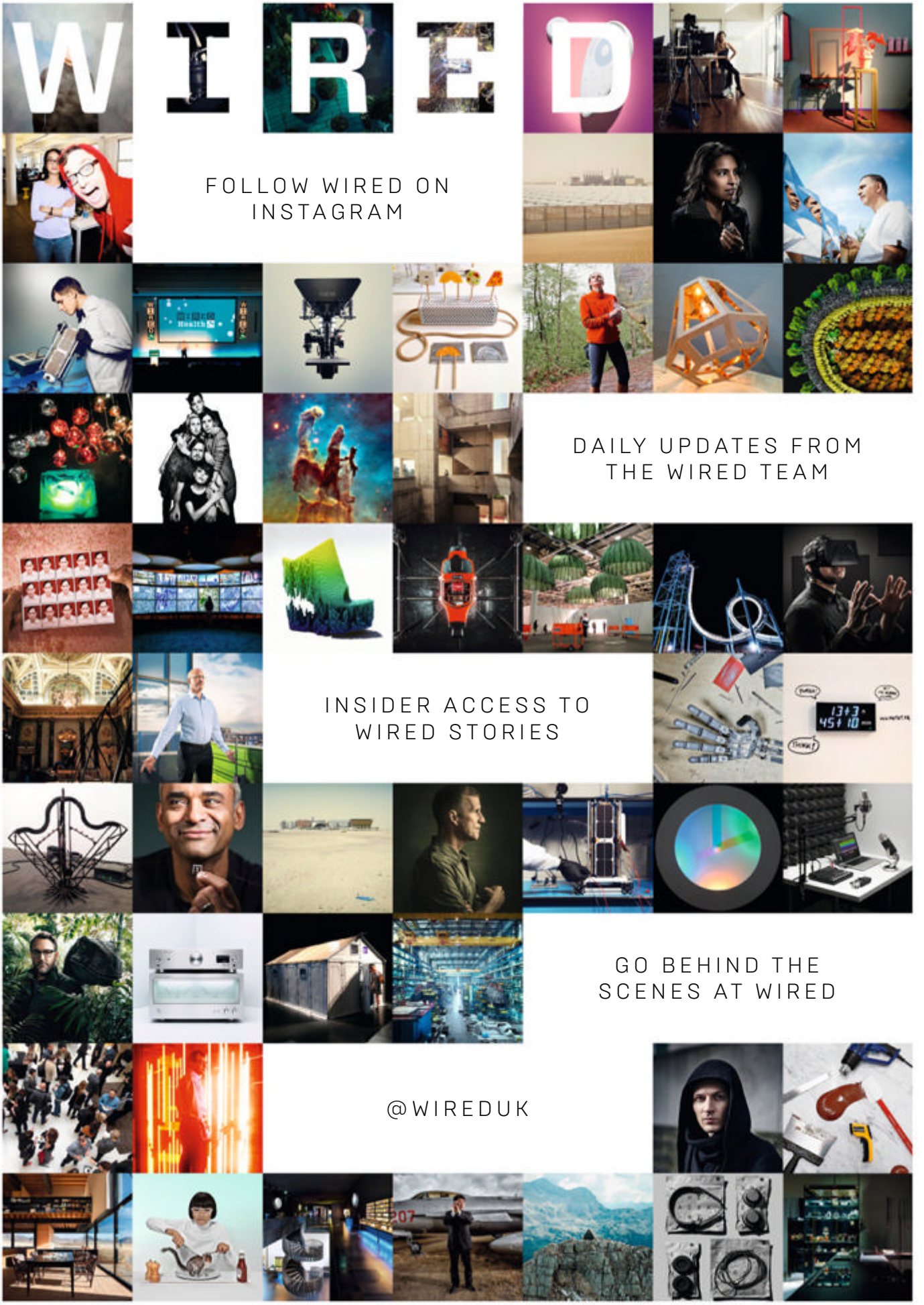
Cut out a strip of 20mm insulation in the shape of the rear thruster. Cut a small strip out of the inside of this thruster a third of the way in from the concave portion and 10mm deep. Glue the larger piece on to the rear top of the *Falcon*, using the cut-out notch to secure to the body.

9. Add lights

Attach the piece that was cut out on the bottom of the *Falcon*, directly under the top section, forming a channel in the middle and glue the LED strips inside the channel. Chapuis used blue on top and white on the bottom. Secure the front LED clusters to each of the forward mandibles, and wire the lights so they attach to the power supply.

10. Punch it!

Add any details you'd like, such as a turret on top or a sensor dish. Paint the *Falcon* grey and smoke. Attach the facade and test-fly your new drone-ship. But be warned: Chapuis says his model "handles poorly – 'foamies' are not good fliers." Still, we have a good feeling about this...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FEATURES

ARTWORK: JAMIE JULIEN BROWN. HOW HE MADE IT: RIP, CUT, SPRAY, FADE, PEEL, STICK, SHIFT, OVERLAY, MIX, MARK, MOVE, FIX, DIP, DAUB, DONE

"I quite fancy a drone, because they look like spaceships." Simon Pegg, p84

G E A R

By **Oliver Franklin-Wallis**
Photography: **Gary Salter**

DJI INSPIRE 1
We love this professional-level drone for such useful features as a ready-to-fly system that should see you flying it at altitudes of up to 4,500m in minutes. You can also beam footage from its gimbal-mounted camera to a smart device in 720p HD from up to 2km away. WIRED's favourite function, however, is its dual control capability, which lets one person concentrate on flying the Inspire 1 while another captures killer video. *£2,380 dji.com*

W L E O V E

WANT TO LIVE
THE WIRED LIFE?
OUR STAFF REVEAL
THE ESSENTIAL
KIT THEY CAN'T
LIVE WITHOUT.
GUEST-STARRING
SIMON PEGG

How the hell do you fly this thing?

Simon Pegg: the go-to technology guy
(on screen, at least)

In a studio in north London, the air is pierced by drilling, followed by a sickening crunch and a scream. "Someone just got decapitated by the drone," laughs Simon Pegg.* (A false alarm: it's merely undergoing repairs.) After finishing Nick Frost and Edgar Wright's so-called Cornetto trilogy with 2014's *The World's End*, the British actor/writer/self-confessed super geek (his 2010 memoir, *Nerd Do Well*, contains a chapter of *Star Wars* fan fiction) is back saving the world in July's *Mission: Impossible – Rogue Nation*. Then he'll be back aboard the USS *Enterprise* as chief engineer Montgomery "Scotty" Scott for the new *Star Trek* – the screenplay of which he's also co-writing. Who better to host this year's Gear We Love feature? Here, Pegg talks about quitting Twitter, doing stunts with Tom Cruise and keeping up Gene Roddenberry's sci-fi legacy.

WIRED: When was the last time you fixed something?
Simon Pegg: Never.

But in both *Mission: Impossible* and *Star Trek* you play the tech guy. That isn't true to life?
No! The key to both those characters is that they're fairly light-hearted, which is my specialty – or people assume that it is. I enjoy it, particularly with Benji in *Mission*, because I get to play with a lot of gadgets. Although ironically, the way product placement works, it's not always the stuff I think Benji would use.

Are you the kind of person who buys new tech when it comes out?
I quite fancy a drone, because they look like spaceships. I also want to get an Apple Watch – I'm an Apple whore and quite happy to admit it. It baffles me, the weird tribal animosity that exists between gadget aficionados. But I get along well with Apple products. And of course I'm going to get the Watch, just so I can go "Hello, darling" [mimes into his wrist] to my wife.

It's *Inspector Gadget* come true.
Exactly! I recently started using my GoPro camera when I go snowboarding, and I was alarmed at the brilliance of the results. I ended up just carrying it so I could swing back the camera to look at my own face, just to prove that it was me. GoPro selfie. I remember when I started making home movies on video cameras in the late 80s – they were gigantic, unwieldy low-definition monstrosities.

It's interesting that GoPros seem to be pushing people to even greater extremes in search of footage.
Our relationship to our own experiences is becoming more and more abstract – the need to record everything. There's a new set of snowboarding goggles that have a heads-up display in them, and they record your speed and your altitude. But it shouldn't be about how fast am I going, how high am I – it should just be about: isn't this fun?

You quit Twitter last year. Why?
A number of reasons. I don't try to be a celebrity in my real life, and Twitter is a kind of microcosmic, personal celebrity that you build, one person at a time. I suddenly thought, if I don't want to be famous elsewhere in my life, why should I actively seek it in that one arena? As an actor I think you need to hold on to a bit of mystique so that people are interested in you. I didn't like myself on it. It felt really good to let it go. I'm not on any social media now.

You don't even post anonymously?
I have a Twitter account which is just a dormant reading account, so I follow a lot of the people that I followed before. I just don't tweet any more.

Are you glad you missed out on the whole *Tinder* thing?
I didn't just miss it, I missed it by a long way! It's interesting – it's an incredibly frank kind of social environment. I grew up in the 80s, and my social life was affected by AIDS, when there was a withdrawal from interaction. Even though it is still a huge concern, the fact that it's kind of been brought under control means maybe people are getting more relaxed. Probably unwisely. It's got a little bit like the 60s again; it's just this wholesale fucking everybody thing going on. [Laughs] Part of me is like, oh man, I missed that! But part of me is glad I avoided it.

In *Mission: Impossible – Rogue Nation* you're not just the tech guy, you're an agent.
We had this idea that when he helps Ethan [Hunt, played by Tom Cruise] get through Shanghai [in *Mission: Impossible III*] he gets this little taste for adventure and decides to enrol in the agent programme. So by *Ghost Protocol* [the fourth *Mission: Impossible*] he's out maybe on his second or third mission, and then by the fifth mission he's a bit more experienced and less wet behind the ears. But even then he's still very much in awe of Ethan. Ethan is, literally, Benji's hero – which is really fun to play because it's also a little bit like that in real life. No matter how many times you work with Tom Cruise, you're always like: "It's Tom Cruise!"

He is known for doing his own insane stunts – does that push you to want to do the same thing?
He's incredibly safety conscious. We did a big car chase in Morocco – we didn't have any stunt doubles in that sequence, because he drives brilliantly – and if it was going to be him in the car then it had to be me sitting in the passenger seat too. The car was very close to rolling, and he was always careful to make sure I didn't put my hand out of the window, because if it rolls that's the worse thing you can do. He engenders a spirit of adventure and can-do. These days we just assume things are faked, so it's important for him that there's a bit of leakage so you know he's doing these things.

There's a particularly crazy scene where he is clinging to the outside of an A400 cargo plane as it takes off.
I got on the plane for shits and giggles. In the scene I'm on the ground, but they said, "Do you want to come and have a little fly around?" I sat in the back so I could be near the cargo door when it opened. It was roaring, Tom was outside and he was just having a blast. He has an amazing team – Wade Eastwood, our stunt co-ordinator, is a brilliant, conscientious stunt designer. I remember when we did the Burj Khalifa stunt in Dubai [for *Ghost Protocol*] – going up to the 130th floor, or something – and there's this hive of quiet industry, like, 22 stunt people all holding on to his wires. He never does anything gung-ho.

It seems like he's fun to work with.
He is immense fun. The thing is, there's this dense thicket of mystery around him, which he just allows to grow. He's complex, but he's more ordinary than people assume – he's just a very driven guy from Kentucky who wants to do shit right, you know? All the assumptions and prejudices people have about him are vastly off the truth.

Do you feel you could go off and hold one of those franchises yourself?
I'm waiting for the Benji spin-off, absolutely. The last one, they were kind of grooming Jeremy Renner's character [William Brandt] to be the next Ethan Hunt, but Tom had such a good time that he was like, "You know what? I want to do a few more of these." So hopefully by that time Jeremy will be off doing his *Bourne* spin-offs and *Avengers* stuff and it will just be *Benji: The Movie*.

You took your daughter to the set of *Star Wars: The Force Awakens*. That must have been amazing.
Extraordinary. It's like manifest destiny. That film is the reason I developed such a passion for cinema, so to be there watching it get made – and in such a faithful and loving way – was a real joy. I've never been so not bored on a film set. It was awesome to just sit around and talk to C-3PO and stuff.

What are your memories of Leonard Nimoy [who died in February]?
Just a genuinely beloved soul. My favourite memory of him is of me, Chris [Pine] and him. We were shooting at the Budweiser plant in LA and we went back to our trailer one night, and Leonard fell asleep, sitting up, in full Spock gear. He's snoring quietly to himself, and me and

Chris are sat there not wanting to make a sound because he's asleep, just looking at each other like, "there's Spock... and he's snoring." [Laughs] It's a highlight of my career, to act with a character I have known since I was a child.

You're writing *Star Trek 3*. What's it like to be given that responsibility?
Terrifying.

Does it make you consider the meaning of the *Star Trek* universe?
You're forced to bring into focus what it is that it's actually about. And it is a very human story, *Star Trek*. Writing for characters like Spock and Kirk, you're aware that it's literally 50 years of history there. You want to advance it, but at the same time you have to ground it in what's come before.

The TV series was pioneering in how it dealt with contemporary social issues at the time. Do you have to pay attention to the news now?
I don't think you have to pay attention particularly, because those things emerge subconsciously anyway. Any expression of art always reflects the preoccupations and fears of the collective subconscious of the time. One reason *Star Trek* has become a phenomenon is that it's an inclusive universe. It's very idealistic, tolerant, super-integrated – albeit still led seemingly by white human beings! But the thrust of it, [*Star Trek* creator, Gene] Roddenberry's desire was to make this future world where the notion of integration wasn't even an issue. I mean – to have a Russian pilot ensign on board the *Enterprise* at the height of the cold war? That was such wishful thinking. I think *Star Trek* featured the first interracial kiss on TV. So I want to make sure we keep doing that, and keep Roddenberry's dream alive.

Can you say what the film's about?
We're not at screenplay stage yet. We're still at story outline stage. Pretty soon we're going to have to start putting words in these characters' mouths, and it's daunting. We have three months. And we have production inevitably banging on the door saying, "What are we designing? What are we making?"

The *Enterprise*?
[Laughs] We can start with that: the bridge set. That's a given. But it's like, "How many spaceships are in this?" "Er, I don't know... five?"

You're also working on a new film with Nick Frost and Edgar Wright?
We know roughly what it is. We've just got to find time when we can do it. We're going to have regular Skype chats and try and gather enough material so that we can hit the ground running.

Turn the page for Simon Pegg's spy kit, plus the complete Gear We Love list

* NO HUMANS WERE SERIOUSLY HARMED DURING THIS PHOTO SHOOT

GEAR

1

WELCOME TO OUR GUIDE TO LIVING THE WIRED LIFE. CURATED BY THE WIRED TEAM, THIS IS A SHOWCASE OF EVERYTHING AWESOME THAT HAS CROSSED OUR DESKS OVER THE LAST 12 MONTHS, FROM SUPER-OFF-ROAD VEHICLES TO MOLECULAR BUILDING SETS

WORDS BY KIERAN ALGER, ANDREW DIPROSE, CHRIS HASLAM, JOE MINIHANE, JEREMY WHITE AND KATHRYN NAVE.

W E L O V E

2

PHOTOGRAPHY:

STEPHEN LENTHALL

1 BUSTER + PUNCH: HEAVY METAL
Machined from solid steel and attached to a matt black rubber cord, this pendant comes in three choices of finish: raw steel, smoked bronze or rose copper. *From £160 (inc bulb) busterandpunch.com*

2 FFERRONE DESIGN REVOLUTION WINE AND WATER GLASS
Striking and surprisingly versatile glassware made from borosilicate, which looks delicate but can cope with hot tea, the deep freeze and dishwashers. *$84 (for two) fferronedesign.com*

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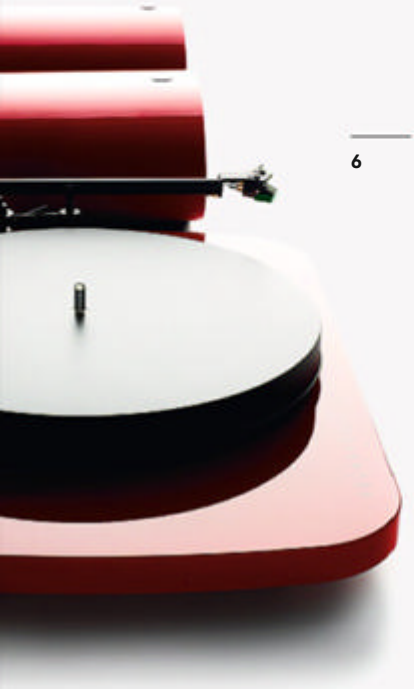

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3 NENDO CUBIC RUBBER BAND
A utilitarian reboot from Japan, these 3D rubber cubes re-imagine the elastic band. Practical, stylish and anything but throwaway – at roughly £10 for three, they're not for flicking across the office. *¥1,080 nendo.jp*

4 PENHALIGON'S AS SAWIRA
Taking inspiration from Essaouira, Morocco's first seaport, this cologne has bermagot and saffron underscored by absinthe and davana, plus a smoky mix of sandalwood and myrrh. *£150 penhaligons.com*

5 SILENT CIRCLE BLACKPHONE 2
Aiming to give us back our privacy, this smartphone has PrivatOS – a custom Android mod – and apps that encrypt everything, prevent signals being tracked, and keep your sensitive info in a secure place. *£tbc blackphone.ch*

6 MERLIN 1
Enjoy vinyl via the high-quality "friction free" turntable or stream CD-quality audio via Bluetooth aptX through two 24-bit, 192kHz DACs and twin amps. Add in an analogue converter and rip everything. *£1,300 musicalfidelity.com*

7 IMPOSSIBLE PROJECT INSTANT LAB UNIVERSAL
This Polaroid-style camera and micro darkroom exposes images on your smartphone and develops prints. You can also apply traditional photo-trickery such as double-and over-exposures. *£150 the-impossible-project.com*

8 FLARIS LAR01
This luxury Polish-built single-engine jet can take off and land on grass runways as short as 250m, reach 700kph and travel distances of more than 2,500km – and there's a parachute packed in the nose for reassurance. *$1.5 million flaris.pl*

9 RIG TIG STELTON PARMESAN MILL
By putting your hunk of Reggiano inside the grater it not only stops the cheese spraying the table, it also means over-zealous graters can store the excess by popping the mill in the fridge. *150 DKK rig-tig.com*

10 GIRSBERGER G 125 CHAIR
Designed by Mathias Seiler to mark the firm's 125th anniversary, this reinterpretation of the swivel chair won a Red Dot: Best of the Best award. It's made in Switzerland from solid timber. *£poa girsberger.com*

11 GLOWPEAR URBAN GARDEN
These self-watering modern modular planters are designed for those who appreciate foliage but can't keep a cactus alive. Plants are watered using a reservoir system. *$199 glowpear.com.au*

12 REACH79 SIGNAL BOOSTING IPHONE 6 CASE
With a built-in micro-thin gold-plated antenna, Reach79 claims its case can double an iPhone 6's signal. Useful for boosting data speeds and killing 4G/LTE-coverage dead spots. *From $60 reach79.com*

13 RAINS SKY BLUE JACKET
Danish brand Rains makes truly stylish waterproof kit. We especially like the bright blue, matt finish on this classic hooded rain jacket. Plus all inside seams are bonded using ultrasonic welding for total dryness. *£75 rains.dk*

PHOTOGRAPHY: GARY SALTER; DAVE LIDWELL

78 PRODUCTS -WITH- EXTRA WIREDNESS

'THREE-WAY ACTIVE STEREO SPEAKER POWER – ENGAAAAGE!'

14 RAUMFELD MULTI-ROOM
Raumfeld's lossless system is a real alternative to streaming leader SONOS. The German-designed range can be controlled by iOS and Android apps, and includes the Stereo M (*left, right*) and Stereo Cube (*centre*). *From £149 to £899 raumfeld.com*

15 MERCEDES
G-CLASS 4X4²
A brutish and unapologetic design from Mercedes, the G-Class 4x4² features a bi-turbo 4.0-litre V8 engine, boulder-conquering 450mm ground clearance, 22" wheels, 416bhp and a hefty 238 kg/m² of torque. At nearly 2.5-metres tall and with slick carbon-fibre trim, its advanced ruggedisation is, perhaps, a little unnecessary for the school run – but off-road it's extraordinary.
£tbc mercedes-benz.com

PHOTOGRAPHY CHARLIE SURBEY ROGER STILLMAN

16

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16 MOTI
Designed to help form good habits through repetition, this cute blob sits in the corner and reminds you with blips and beeps until you finish the task you wanted it to remind you of. It's simple – and a lot more fun than a phone alert. *$tbc moti.io*

17 MICROSOFT HOLOLENS
Wearing this VR headset lets you visit a holographic world where apps are displayed as avatars in your home and are accessible via hand gestures. The ability to move and resize your TV to any wall gets WIRED's attention. *$tbc microsoft.com*

18 RAY-BAN REMIX
Shun the mass market and make your own bespoke sunnies. WIRED's own art department went for Original Wayfarers with a dove grey front and matte pink arms, plus some appropriate engraving on the temple tips. *From £135 ray-ban.com*

19 POP PADDLEBOARDS
Perfect for cross-training without a gym, POP's paddleboards come as both fibreglass-coated foam-core models, like the 3.5m Throwback (*above*), or as a 3.3m inflatable that fits into a backpack. *From $875 to $1,149 poppaddleboards.com*

20 APPLE FOLDING PLUG
The rest of the world may look on in bewilderment, but Apple's eminently sensible and elegantly executed UK folding-pin USB adapter is a MoMa-worthy piece of engineering. Simple, practical, perfect. *£25 apple.com*

21 PAPERLUX PETIT FOU
More *objet d'art* than practical, these handmade paper clutches are about the most eye-catching, perfectly engineered bag WIRED has ever seen. Choose between two sizes and six colours – just don't get them wet. *€23 petit-fou.com*

22 BIONIC BIRD
The world's first bird-friendly drone looks and flies like its namesake. Charging is via a portable egg-shaped battery storing juice for ten refuels. This allows the smartphone-controlled bird to fly up to 100m or about ten minutes. *€119 mybionicbird.com*

23 VOCIER C38
Get more in overhead with this ultra-light aluminium and Italian black leather case that has a compartment to keep two suits mercifully wrinkle-free and a fibre-reinforced plastic frame to keep valuables from harm. *£545 vocier.com*

24 HEYS STEALTH LUGGAGE
The giant tortoise of the baggage carousel, this polycarbonate shell suitcase has ingenious fold-flat, stow-away aluminium wheels. Available in 53cm, 66cm and 76cm. *From $250 heys.com*

25 NIKE MOG BOLT BACKPACK
Designed not to disrupt your stride, this lightweight kitbag features an armadillo-style back section that retracts (or expands), as you shed layers on a long run, and the chest strap minimises bounce. *£65 nike.com*

26 KAUFMANN MERCANTILE WATERPROOF WAXED CANVAS LUNCH BAG
Give your packed lunch some kudos with this tough wax cotton canvas pouch complete with oil-tanned strap and riveted joints for durability. *£35 store.kaufmann-mercantile.com*

23 24

25 26

27

27 FUTURE MAPPING COMPANY
Change the way you look at the world with this wall-sized equal-area projection map, which shows countries in their correct proportions. Choose colour schemes, mounting options and sizes. *From £25 futuremaps.com*

CUSTOM TYPE
WIRED chose to engrave using Arial, but you can also pick from Trade Gothic and Monotype Corsiva

28 UNILLOY IRON POT
This hollow cooking pot blends traditional casting techniques from Japan's Tsubame Sanjo production centre with a new approach to moulding that creates crazily thin 2mm walls and a bottom that's a mere 2.5mm thick. *£225 unilloy.com*

29 THE JUICE WELL GINGER SHOT
This concentrated hit of ginger prevents motion sickness and nausea, and works as an anti-inflammatory and blood thinner. Not recommended to those who are pregnant. *£4 thejuicewell.hk*

30 PININFARINA CAMBIANO PEN
Thanks to its hand-forged ethergraf tip, this ink-less pen never runs out. The metal alloy oxidises on contact with paper, but wears down so slowly that it will outlast us all. *£99 pininfarina.com*

31 TENTSILE STINGRAY
A clever twist on a classic tent, this literally takes camping to another level. A collapsible triple-hammock tree-house that was inspired by spider webs, it lets occupants sit secured between three trees. *£540 tentsile.com*

32 POPPY POUR OVER
This achingly stylish app-controlled bean-to-cup pour-over coffee maker monitors bean levels and automatically puts in an order to Amazon's Dash grocery service so that you never run out. *$tbc poppyhome.com*

33 SRIRACHA2GO
Sriracha sauce aficionados no longer need to rely on the restaurateur for their sticky fix of garlic, chillies and vinegar, thanks to this 36ml travel bottle. It comes complete with a handy carabiner clip. *$7 sriracha2go.com*

34 NUTRIBULLET
Using cyclone technology and a brutish little 600W motor, this "extracts" rather than juices, essentially blitzing seeds, stalks and stems of all hard-to-juice veg for a concentrated nutrient smoothie. *£100 nutribullet.co.uk*

35 ROSALIE MCMILLAN JAVA ROCK NECKLACE
This necklace isn't just inspired by the shapes of coffee grounds, it's made from them. It fuses 22ct gold vermeil and Çurface, which is derived from coffee, turning grounds into bling. *£415 rosaliemcmillan.com*

36 KNOMO ELEKTRONISTA
Stitched from lightly tumbled soft, smooth, full-grain leather, this clutch is built for the tech savvy with pockets and slots for cabling, a large padded tablet slot and built-in 3000mAh battery. *£249 knomobags.com*

37 BYREDO APOCALYPTIC
Ever wondered what a "depleted primordial forest" smells like? That's the inspiration behind Apocalyptic, a warm, woody and totally luxurious candle that features black raspberry and oakmoss. *£50 byredo.com*

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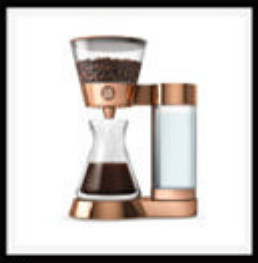

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38 SUPREME/BRAUN TRAVEL ALARM CLOCK
This take on Braun's classic travel clock keeps the quiet quartz movement and crescendo alarm, but adds a motion-activated snooze, mini light and flip-down lid showing time zones. *$60 supremenewyork.com*

TAKE THE HEAT

According to the chemistry faculty at the University of Bristol, if you have misjudged the heat of a pepper, water and beer will be of little help. Tequila has a high enough ethanol content to provide some respite, but the greatest relief comes from fatty foods and dairy products. It's no surprise, then, that many curries include cream or butter, and that Mexican food is often served with a side of soured cream.

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39 OKKI NOKKI
If you've got stacks of pristine presses or a box of tatty classics, this record cleaner will have them all sounding better. Squirt on the cleaner, rub in with the brush, and let the vacuum arm suck your groove clean. *£390 okkinokki.co.uk*

PHOTOGRAPHY: GARY SALTER; DAVE LOWELL

40 KALEIDO TRAYS
Designed by Clara von Zweigbergk, these painted steel geometric trays nestle within one another and can also fit together side by side. Great on their own; even better arranged in striking groups.
From 89 DKK hayshop.dk

41 STUDHORSE OUTLOOK, WASHINGTON STATE
Just 50 kilometres from the Canadian border, this Olson Kundig–designed family home sits in the 100-kilometre-long Methow Valley in the northern Cascades. The various buildings and rooms are arranged around a central courtyard, and evoke the circled wagons of the pioneers. The glass walls of each unit can open completely and offer 360° views of the landscape.
olsonkundigarchitects.com

42 FERM LIVING MOLECULE BUILDING SET
Unravel the mysteries of the Universe with this elegant beech and maple building-block kit. Featuring 24 "molecules" and enough wooden sticks with which to re-imagine photosynthesis.
£49 fermliving.com

43 TOYOTA I-ROAD
Is the electric i-Road a car that thinks it's a motorbike or a motorbike that thinks it's a car? Powered by lithium-ion batteries with a 50km range, its front wheels can turn separately for optimal cornering. *£tbc toyota-global.com*

44 TROY-BILT FLEX SYSTEM
A simple click lets you lock and load a whole range of attachments to one main 208cc OHV, all-season four-cycle engine: lawnmower, leaf blower, snow thrower and pressure washer. *From $399 troybilt.com*

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DIGITAL GALLERY
Show off your 4K screen with *Joyousness* by Damien Hirst, a digital piece optimised for HD display. *£8 seditionart.com*

45 SCHOOL OF LIFE BOOKS
Each of the three notebooks in this pack features a primer to a key artist in the Pop Art movement. The short bios of Lichtenstein, Caulfield and Warhol should give ample inspiration for the blank pages that follow. *£15 theschooloflife.com*

46 UKA NAIL OILS
This argan oil–based nail treatment is ideal for cracked cuticles. Created by Tokyo manicurist Kiho Watanabe, it hydrates and nourishes, and combines aromatherapy scents such as hinoki and yuzu. *£17 fortnumandmason.com*

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ALSO AVAILABLE IN GREY, BLUE, BLACK, PINK AND TURQUOISE →

47 SONY X9 TV
The wedge form of Sony's eight-million-pixel, 4K TV creates space for a set of larger front-facing magnetic fluid speakers that kick out higher-quality sound and also doubles as ballast, giving the X9 a lower centre of gravity. *£3,199 sony.co.uk*

48 XOO POWER BELT
Designed in collaboration with British fashion house Casely-Hayford, the stylishly unobtrusive XOO belt contains six hidden layers of flexible lithium ceramic polymer battery, sandwiched between a full-grain leather outer. *$149 xoo.co*

49 SAMSUNG T1 PORTABLE SSD
This chic and svelte external drive from Samsung is business card–sized, but offers up to 1TB of encrypted storage space. Ideal if you don't want to leave your life entirely in the cloud. *From £121 samsung.com*

50 DUNCAN HELLMERS: BLUB UNO
Fusing machined aluminium and bamboo with a nixie tube, the USB-powered Blub Uno displays time, date and temperature. A remote lets you choose transition options and backlight colour. *From $349 blub.com.au*

51 MAHABIS SLIPPERS
Mahabis are slippers for people who don't do slippers. Super-lightweight and all-day comfy, they ship with a detachable cushioned neoprene sole, so you can go to the shops or run after the courier without changing. *£59 mahabis.com*

WIRED'S AWESOME APPS

SLACK
Archive every word of every message, document, spreadsheet or code your team creates in a neat searchable index. *Free for personal use slack.com*

CITYMAPPER
This routing app covers taxis, bikes, public transport, walking, and (naturally) jet pack for 22 cities. *Android, iOS free citymapper.com*

DOJO
Dojo selects places and events across London, then provides options, including *Uber* and *Citymapper*, to get you there. *Android, iOS free dojoapp.co*

VELOCITY
This restaurant-bill app lets you view orders, pay remotely, and easily split a tab among multiple accounts. *Android, iOS free paywithvelocity.com*

CIRCA NEWS
Follow particular stories via a daily briefing update, plus a selection of curated editors' picks. *Android, iOS free circanews.com*

SPOTIFY RUNNING
Serving playlists to match your speed, the idea here is to keep you moving. Nike+ integration is on its way. *Android, iOS free spotify.com/running*

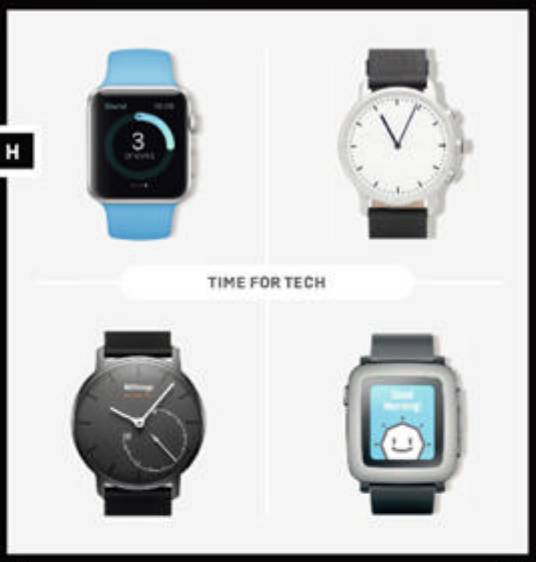
PRODUCT HUNT
Product Hunt is a reddit-style forum for the latest product developments the tech world is obsessing over. *iOS free producthunt.com*

VSCO CAM
More subtle than *Instagram*'s filters, VSCO offers emulations of photographic films, plus picture editing. *Android, iOS free (plus iap) vsco.co*

PHOTOGRAPHY: BENJAMIN BENSCHNEIDER (PREVIOUS SPREAD); ROGER STILLMAN

FETISH

TIME FOR TECH



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78 PRODUCTS WITH EXTRA WIREDNESS

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NOW HEAR THIS

Pair the P5s with Holly Herndon's tech-topia-tastic new album *Platform*

52 LE CORD IPHONE CABLE
Wrapped in knitted fabric for added durability, these fine textile cables are Apple certified. Available in 19 designs, such as Camo (*shown*), and luxurious options in woven leather with wooden connectors. *From €30 lecord.se*

53 APPLE WATCH
Hotly tipped to kickstart a wearable-tech revolution, Apple's slick timepiece comes in two sizes, 38mm and 44mm, and 38 designs. Discrete taps on your wrist let you know everything from directions to alerts. *From £299 apple.com/uk*

54 NEVO SMARTWATCH
The product of French designers and Swiss timekeepers, the nevo has a stainless-steel case, sapphire glass and a choice of straps. There's also solar charging, activity tracking, plus an LED for phone alerts. *£240 nevowatch.com*

55 WITHINGS ACTIVITÉ POP
The Pop is a health-focused timepiece that brings much-needed class to smartwatches. Behind its elegant design and subtle clock there's a range of tracking smarts. *£120 withings.com*

56 PEBBLE TIME
The streamlined incarnation of Pebble's smartwatch comes with a snappy colour e-paper display. It also has a built-in water-resistant microphone, seven-day battery life and Jawbone and Misfit apps for active types. *£tbc getpebble.com*

57 GIRO NEW ROAD
With obsessive technical detailing, block-colour fabrics, understated styling and tiny logos, the New Road jacket is kit for urban minimalists and laid-back riders who don't want to look like they are part of a race team. *£130 giro.com*

58 HIUT LOW LIGHTERS
These UK-made jeans may look a bit leftfield down the pub – it's a bit like having catseyes all over your trousers. For extra urban credentials, the reflective pattern is based on skyscrapers at night. *£tbc hiutdenim.co.uk*

59 OAKLEY JAWBREAKER
These 27-component sunglasses allow for lens changes and for the arms to be adjusted. The curved shape maximises field of view while the Prizm Road lenses enhances your view of road-surface textures. *From £180 oakley.com*

60 B&W P5 WIRELESS HEADPHONES
B&W has added Bluetooth to its classic P5s. So you get the quality leather and aluminium build, but with aptX wireless streaming. The rechargeable battery is good for about ten hours. *£330 bowers-wilkins.co.uk*

61 THE CALIFORNIA SUNDAY MAGAZINE
With its clean-yet-clever creative direction by Leo Jung (ex-design director of WIRED US) and an inspiring reverence for photography, this is oft pored over by our art department. *Subs from $40 californiasunday.com*

62 JOSEPH JOSEPH CAN-DO CAN OPENER
From the dual brains of the Joseph twins, the Can-Do is for both righties and lefties. Clip it on to any can, twist the middle handle, and release the lid by pressing the button. *£15 josephjoseph.com*

63 GRAMOFON
Turning old stereos into Wi-Fi streaming systems, Gramofon is a discreet way to hear tunes usually shackled to your phone or laptop. It supports Spotify, naturally, with TIDAL also due to get on board this year. *€59 gramofon.com*

PHOTOGRAPHY: SUN LEE, GARY SALTER, JESSE SIMMONDS

64 JONES PLUS FRAME
Jeff Jones has been designing bikes since 2002 and he's rightly gained a near mythical reputation as a designer uninfluenced by fashion or fads. His latest release, the (29er) Plus, takes "fat bike" tyres up to three inches. Add a long and confident geometry and you have a frame that's as happy bike-packing across continents as it is shredding local tech trails. *Jones Plus frame £1,350 (as pictured £3,000) jonesbikes.com*

65 MACBOOK IN GOLD
At 13.1mm and 0.9kg, this lean machine is 24 per cent thinner than Apple's 11-inch MacBook Air and bursting with new ideas. The edge-to-edge keyboard has been completely re-engineered; the 12-inch retina screen packs in a mighty three million pixels; and a new "Force Touch" trackpad adds pressure-sensitive gestures and haptic feedback. And, despite its complete lack of ports, 100 per cent of the WIRED office wants one. *From £1,049 apple.com*

NONDA HUB+
The single USB-C port on the MacBook has led to the creation of this Kickstarter-funded hub. With USB, Thunderbolt and SD support, plus a portable phone battery, it's an Apple essential. *£tbc nonda.co*

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68 VOR 1-A SOLE
Bavarian minimalists Andreas Klingseisen and Jörg Rohwer-Kahlmann, the brains behind the intricate full-grain leather craft, pride themselves on eliminating every superfluous detail from their simple footwear. *€329 vor-produkte.com*

Digital extra!
Download the WIRED app to read extended reviews of key products

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66 CANON XC10
This DSLR-sized 4K camcorder boasts 3,840 x 2,160 res, 12MP stills, a fixed 10x optical zoom, image stabilisation and Wi-Fi. It's ideal for aspiring cinematographers and professionals on a budget. *£1,599 canon.co.uk*

67 THE ART OF HE-MAN
By the power of Grayskull! This hefty tome chronicles the history of He-Man and She-Ra, from Mattel's *Star-Wars*-meets-*Conan* toy line to hit TV sensation. There's also a castle-shaped limited edition version for true He-fans. *£30 darkhorse.com*

69 SMARTGRILL BY LYNX
Connected to the internet of delicious things, Lynx's Smartgrill can be controlled via iOS and Android apps. It can also respond to voice commands, getting temperatures perfect for whatever you're cooking up. *From $5,999 lynxgrills.com*

70 TIKO 3D PRINTER
The TIKO is 3D printing re-engineered for the masses. There's a built-in accelerometer that provides auto-calibration, and cloud connectivity lets you print with 50-micron precision, even from a smartphone. *$179 tiko3d.com*

71 MIFOLD
Forged from super-tough polymers and aircraft-grade aluminium, this grab-and-go ultra-portable child's car seat is ten times smaller than a regular booster. It's crash tested, fits in a handbag and is even dishwasher friendly. *£tbc mifold.com*

72 THINK GEEK: EXECUTIVE BUILDING-BRICK SET
Think Geek's 24k gold-plated construction sets contain eight two-by-four solid metal blocks, all fully compatible with more pedestrian bricks. *$25 thinkgeek.com*

73 VOLVO XC90
Volvo claims the XC90 is the most luxurious it's ever built. The seven-seater SUV has touchscreen controls, a heads-up display and voice-activated music that'll let you play Springsteen by saying "Play the Boss". *From £45,750 volvocars.com*

PEGG'S SUPER-SPY PICKS

WIRED challenged Simon Pegg to assemble his ultimate action survival kit. Mission: accomplished...

74 RECON JET GLASSES
This ultra-sports version of Google Glass is described as a "wearable microcomputer and display". Weighing just 60g, the Jet has a dual-core processor, Wi-Fi, Bluetooth 4.0, GPS and a POV HD camera. *£580 reconinstruments.com*

75 BUSHNELL 1-X42 LEGEND ULTRA HD MONOCULAR
With 10x magnification, this high-powered monocular is ideal for spies, pirates and anyone else interested in seeing objects in crystal HD up close from far away. *£199 bushnell.com*

76 GARMIN GPSMAP 64S
This handheld GPS ensures you won't get lost. A 2.6-in sunlight-readable colour screen, 3.5GB memory, Bluetooth connectivity and a barometric altimeter and three-axis compass should be enough to keep you out of trouble. *£280 garmin.com*

77 MOTOROLA T80 EXTREME
The all-weather T80 walkie talkie has a range of 10km, is water-resistant, has a backlit LCD, eight channels and no call charges. Use it hands-free – or when darkness descends, activate the torch. *£76 motorolasolutions.com*

78 GOPRO HERO4
The daddy of action cams brings you 4K video at 30fps and 1080p at up to 120fps. There's also Wi-Fi, Bluetooth, a sturdy casing and mount, plus a lens with a 170° field of view. And yes, it does look practically identical to the HERO3+. *£280 gopro.com*

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PHOTOGRAPHY: GARY SALTER; DAVE LIDWELL


*以后定律
By Andrew "bunnie" Huang
Moore's law is slowing. In Shenzhen, that means phones are becoming modular, upgradable – and even open-source
SUNG
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中国联通
CHINA YONICOM
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白象手机
WHITE ELEPHANT
SMARTPHONE
NOKIA
白象手机
话费充值
TOP UP

在深圳七月份闷热的天，华强区的街头好像有菜市，但买不到荤腥，只有电子产品的摊子。*

***It's a muggy July day in the Hua Qiang district of Shenzhen. Spread across several blocks, it's reminiscent of a wet market, except instead of fish and meat, the stall-holders are hawking circuit-board components and mobile phones.**

WIRED is with Roger Wang, a scrappy, bright-eyed local who specialises in sourcing electronics for his employer, engineering and manufacturing company AQS. Our quarry today: the Hongmi 1S, made by the mobile-phone startup phenomenon Xiaomi, the most popular device manufacturer in China.

Reworking the supply and demand equation, Xiaomi limits availability through online-only flash sales. Tightly controlled and lean, this model allows the manufacturer to sell phones at near cost to the fortunate few who can catch a flash sale before supplies run out. Many phones end up in the hands of touts, and our challenge is to find a couple of authentic Hongmi 1S models for the best price.

Bobbing and weaving through the crowds, Wang leads me into the Yuanwang Digital Shopping Center, a trading floor for mobile phones that's crammed with hundreds of stalls. Transactions are strictly cash-only, so serious buyers arrive with stacks of banknotes several centimetres high, and every stall has safes lining the wall. If you don't need a purse for your cash, you're a tourist; if you're a tourist, you'll be duped. So WIRED is carrying a shoulder bag, even though our stack of cash is only a centimetre thick.

Wang leads WIRED to a run-down stall near the back of the market, where we're presented with two shrink-wrapped kraft boxes. The stall's owner is asking 800RMB (£90) each, which is £11.50 over the flash-sale price. Suspicious of fakes, we reveal serial numbers hidden by a scratch-off code and check them against Xiaomi's website. They're authentic – at least, the boxes are. We power them up and check the kernel and baseband version numbers. As we run tests, other buyers come in and buy phones. Bricks of cash change hands, money-counting machines churn, receipts are drawn. Satisfied the phones are legit, WIRED slaps its money on the table and melts into the din of the market.

Despite its low price, the Hongmi 1S is a solid piece of hardware with great battery life. It's powered by a 1.6GHz quad-core Snapdragon 400 – a reasonable alternative, at a fraction of the price, to the Samsung S3's 1.4 GHz quad-core Exynos 4412. The milling crowds of customers who throng the market seem to agree – more than 60 million Xiaomi smartphones were sold in 2014. How is it that Xiaomi, which was only founded in 2010, could grow into a credible threat to Samsung and Apple in just five short years?

Part of the answer lies in the silicon itself. There are hundreds of millions of transistors inside a processor. The quality of a transistor is dominated by a single metric known as "gate length". Simply put, smaller is better, and for the past 50 years, gate lengths have been dropping by about 16 per cent each year. Gordon Moore, co-founder of Intel, predicted this trend in 1965 in a famous paper, "Cramming More Components on to Integrated Circuits", in the process coining the term "Moore's law".

If only physics were so simple that we could reduce anything to a single curve shooting off to infinity. In the autumn of 2001, Paul Otellini, then EVP and GM of the Intel Architecture Group, proclaimed that the Pentium 4 architecture would hit speeds of 10GHz over its lifetime. It's now 2015, and the chances are that you're using a machine running at a speed much lower than 5GHz. In fact, Intel did an abrupt about-face in 2004, when it reorganised around the Core line, focusing on multiple central processing units (CPUs) over more MHz. The premise behind the Pentium 4 internal architecture was so flawed that it was taken out back and shot; the architecture of today's Core line is actually a descendent of the Pentium III.

"The complexity for minimum component costs has increased at a rate of roughly a factor of two per year. Certainly over the short-term, this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least ten years." *Gordon Moore, 1965*

So what happened? It turns out that the speed enhancements that came with halving gate lengths of transistors tapped out about a decade ago when niggling physics problems conspired to drive power consumption through the roof. The Pentium 4 could scale to 10GHz, but its double-pumped ALU (the arithmetic logic unit is an important part of the CPU) architecture would generate the heat of a blast furnace, and nobody wants that anywhere near their lap. The clear, bright line of Moore's law was starting to become fuzzy as various real-world constraints began to set in.

The principal constraint limiting performance is the amount of battery life we desire, or, if we're considering the desktop, how much cooling we're able to throw at the CPU. Looking at the landscape in another light, the normalisation of MHz across platforms means that even incredibly youthful upstarts, such as Xiaomi in the ultra-competitive smartphone market, can launch homespun products that boast a performance that's easily comparable to that of more established incumbents.

Unlike the MHz race, the rule of Moore's law (to bring you twice the number of transistors every two years) has so far held strong. SSDs (solid-state disks, a data-storage device) now pack more than a terabyte; high-end desktops sport a dozen CPU cores; and graphics processing units (GPUs) tout thousands of cores. This ability to bring you twice the amount of goodness for the same cost is known as cost scaling.

Moore's law – and the cost-scaling benefits associated with it – has been so reliable because the underlying principle is so simple. Any student who has tweaked font sizes to fit an essay within a page limit has discovered the basis of Moore's law. Open a text-only document, and reduce the font size by 50 per cent. You've taken the same amount of information and crammed it into half as many pages. Congratulations, you've reduced the cost to print your document by half! As printers spit out pages at a fixed rate, you've doubled the rate of information flow out of the printer. You've now done both cost and performance scaling, Moore's-law style.

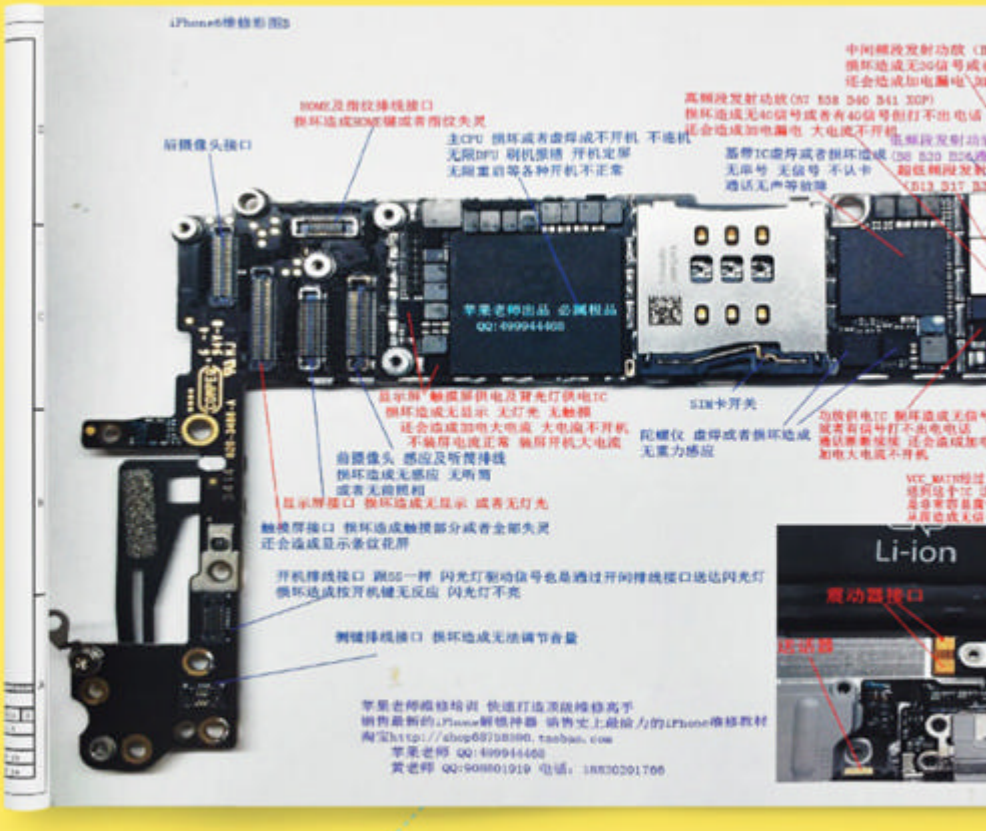
Gate-length scaling for transistors pretty much works exactly like the printer example: the industry has been reducing the "font size" of circuits printed on a silicon wafer year after year. The problem is, we're now approaching the point where transistors are just a few atoms wide. The industry is now facing the same problem you'd have shrinking fonts on your screen: once text is just a few pixels tall, reducing the font any further makes the text illegible. Proposed alternatives, such as 3D stacking and alternative material systems, may provide a one-time extension to Moore's law, but none of the proposals feature the clockwork elegance of gate-length scaling; no proposal charts a similar path for several more orders of magnitude cost and performance improvements. The next step is quantum computers. Unfortunately, these are highly specialised and will probably require cryogenic cooling for the foreseeable future. In other words, don't expect one in your pocket in the next decade or so.

Cost scaling means Moore's law is like the LIBOR interbank rate, but for the computer industry. Shrinking gate lengths have meant 30 per cent more transistors per year for the same-sized fleck of silicon (transistors are laid out in a two-dimensional array, so gate-length scaling improves density in two dimensions). It's as if the entire computer industry is backed by a government bond that appreciates at a rate of 30 per cent every year. Compound interest is a powerful force: a deflection of a few per cent in the interest rate can push an entire economy into or out of a recession. Similarly, even a few per cent reduction in the rate of Moore's law should have an incredible impact that will ripple throughout the computer industry.

Despite the billions of dollars funnelled into next-generation factories, we can see evidence today that cost scaling is reaching its limits. GPUs: they are a bellwether for cost scaling. They're built using thousands of processing units, so there's a direct correlation between performance, cost and how many transistors you can cram into a given piece of silicon.

Back in 2011, when the desktop gaming community was scrambling to upgrade their GPUs to unlock the stunning graphics of the blockbuster game *Skyrim*, trouble was erupting in Hawaii at the International Trade Partner Conference. In a keynote talk, John Chen, vice president of technology at NVIDIA, lambasted its long-time silicon-manufacturing partner,

Taiwan Semiconductor Manufacturing Company (TSMC). NVIDIA's analysis of TSMC's next-generation 20nm and 14nm processors concluded they were worthless: the cost of producing chips had risen faster than the rate at which transistors were shrinking. As a result, those gamers lucky enough to buy a 28nm GPU in 2012 will find that, three years on, their best option is still a 28nm GPU. The Moore's-law bus is a year late, and both NVIDIA and Advanced Misco Devices (AMD) are still waiting in the rain for it to arrive. Although high-value products such as the iPhone 6 and the Samsung Galaxy S6 are shipping today using 20nm and 14nm gate lengths respectively, it seems that a range of products will take a bit longer than usual to enjoy the cost-scaling benefits of Moore's law.



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***Back at the Hua Qiang electronics** market, WIRED continues its quest to measure the pulse of the electronics industry, checking into a favourite district – the Longsheng Telecommunications Market. It's a building that spans an entire block, featuring three floors chocked with vendors hawking mobile phones and phone parts, and stalls offering repair services. Visiting this market is like digging through the electronics industry's trash to learn about its private life. What's selling, what needs fixing, what's being retired, what's getting hacked and what's getting copied – it all happens here.

Brutally efficient and tightly coupled to global supply chains, the Shanzhai (imitations or "improved" versions of brand-name electronics – see WIRED 01.11) traders waste no time on has-been, overhyped or vapourware products. WIRED pays extra attention to the stalls selling tools of the trade; they are often a goldmine for insider information. We eventually find a tool stall, jammed between a battery hawker brazenly attaching authenticity holograms to otherwise fake batteries, and a lady, with a toddler sprawled in her lap, selling vanity bezels for iPhones.

"Chip designs will be required to enable many of the applications on the horizon... and only an open-source approach will provide the necessary freedom and scalability."
Robert Mullins, University of Cambridge

The tool stall is run by a Ms Zou. Shy and diminutive, she speaks softly as WIRED makes enquiries. Her Mandarin is thick with the local Cantonese accent. Sifting through her wares, our eyes alight upon an inconspicuous-looking pile of books buried underneath a pile of solder stencils. Jackpot! It's a mix of books explaining how mobile phones work and how to repair them, and schematics for the iPhone 6, iPhone 5 and a couple of late-model Samsung smartphones. WIRED buys the iPhone 6 schematic book (*above*) for 25 RMB (£2.70).

In the privacy of a hotel room, WIRED peels open the schematics and feasts its eyes on the naughty bits of the iPhone 6. It's like getting a master class on circuit design – WIRED takes notes on the backlight driver it uses, and checks out the measures deployed to mitigate real-world problems such as static electricity and unintentional radio emissions. This writer thinks back to his days at MIT, learning electrical engineering from textbooks: lots of theory, but little practical knowledge. Nowhere in this formal education were these commercially important circuit-design details taught, in part because a professor could not very well include iPhone schematics on the required reading list. Yet for £2.70, engineers in China can get a leg up on the best and brightest university-educated kids by studying these designs. Even if it takes a couple of years and several iterations for a self-taught engineer to reproduce, the resulting product isn't terribly out of date: the iPhone has only undergone a modest increase in clock rate over the past four years, from 1GHz in the iPhone 4 to 1.4GHz in today's iPhone 6. This relative stagnation is endemic, leaving a large window of opportunity for engineers to learn from and emulate the designs of the best.

A knee-jerk reaction to this may be to come down harshly and call for stricter enforcement of IP laws. However, reverse engineering has been judged legal by numerous courts. As a result, one can draw schematics by staring at circuit boards. Unlike source code and its resulting compiled programs, there is a one-to-one correlation between schematic diagrams and circuit-board implementations.

It's also not practical to encrypt or otherwise obfuscate hardware; cost-sensitive consumer electronics need to be easy to inspect and test, which also makes it relatively easy

Top right: the cover of the book that WIRED bought for £2.70 in the Hua Qiang electronics market. It contains, among many other detailed diagrams, this copy of the troubleshooting guide to the iPhone 6 motherboard, (*left*). Components and connectors are labelled with their function, as well as the symptoms if any given component or connection is faulty. *Lower right*: a schematic of the power distribution network within the iPhone 6. It maps the myriad of voltages piped around the motherboard, feeding various subsystems within the device

to reverse engineer. As a result, there are established, legitimate businesses that earn their keep creating schematics from circuit boards. As the pace of Moore's law diminishes, learning through reverse engineering will become increasingly effective, as me-too products will have a larger market window to amortise reverse-engineering efforts before the next new thing comes along.

How much larger is this market window? Even a modest deceleration of Moore's law can have a dramatic effect: a five per cent reduction in the pace of gate-length shrinkage – from 16 per cent to 11 per cent per year – increases the available time to develop products within a technology generation by 50 per cent, from two years up to three.

This additional development time is a boon to time- and resource-constrained organisations, from startups in Shenzhen to university research labs. Open-source hardware in particular stands to benefit from a gradual slowing of Moore's law. Such projects can take years to get off the ground; stacked against Moore's law, a multi-year development cycle would yield a product that's obsolete the day it shipped.

***Times have changed. Take me and** my business partner Sean "xobs" Cross, for example. We're building laptops in a home office. This isn't your Silicon Valley startup: cardboard and old yoga mats line the floor; the 3D printer doubles as a towel hanger. However, over three years we managed to design, build and ship an open-source hardware laptop called Novena.

Three years to ship a computer ought to be ruinous. If Moore's law were holding, we'd expect the Raspberry Pi 2 to clock in at over 2GHz, as extrapolated from Raspberry Pi's debut three years ago at 700 MHz. This would make our 1.2GHz quad-core Novena laptop seem sorely out of date. Happily for us, that's not the case. Although the Raspberry Pi 2 has four cores, they're only clocking at 900MHz. There's a reason the numbers haven't changed much: the Pi CPU, the Pi 2 CPU and Novena's CPU are all made using 40nm technology. Like NVIDIA, for three years our CPU vendors have elected to stay off the Moore's law-bus, relying instead upon circuit-design and architectural improvements to bring more modest gains.

This is possibly the beginning of a larger trend. Instead of running in fear of obsolescence, open-source hardware developers now have time to build communities around platforms; we can learn from each other, share blueprints and iterate prototypes before committing to a final design. The extra time also allows hardware product development to be leaner – one doesn't have to burn money to meet a tight schedule. A team of two can now take three years, working mostly in their spare time, to build a laptop from scratch as a hobby. This is a great time to be developing hardware products, particularly open-source ones.

This trend extends from the system level all the way down to the silicon level. The lowRISC project out of the computer laboratory at the University of Cambridge aims to build an open-source CPU using the RISC V instruction set. "We feel like we are pushing on an open door," says Robert Mullins, a senior lecturer at the University of Cambridge. "Innovative chip designs will be required to enable many of the new exciting applications on the horizon... and only an open-source approach will provide the necessary freedom and scalability." According to Alex Bradbury, a research assistant working with Mullins, the project is about a year from fabrication in either a 40nm or a 28nm process – the same geometries used by Novena, the Raspberry Pi and today's flagship GPUs. According to Bradbury, "there are arguments that 28nm may be the long-term 'value' node, as it seems the cost per transistor rises beyond that." If he's right, it means lowRISC will have an excellent chance of achieving commercially competitive performance despite being a university research project.

Although silicon foundries are still cramming more transistors on to a single chip, they are taking much longer to do so, and at a higher cost than ever. As Moore's law yields, small communities of innovators around the world are given space to gather their strength and build products that may some day compete with mainstream providers. Today's phenomenon of Shanzhai and open hardware is likely to be just the first shot across the bow of traditional corporate juggernauts. ■

Andrew "bunnie" Huang directs Kosagi, a hardware design studio in Singapore, and is a co-founder of Chibitronics

Mike Lynch built Autonomy into Britain's biggest software firm, selling it to HP for $11.7 billion. HP then accused Lynch of inflating Autonomy's value, and sued him for $5.1 billion. Lynch went quiet, even as he denied HP's claims. But now he's back. As the key figure behind security startup **Darktrace**, he's using the same Bayesian approach as Autonomy's to fight cyberattacks. He says it will safeguard Britain's critical infrastructure – and has hired an impressive team of senior spooks. Could Darktrace give Lynch his great second act?

By Tom Cheshire

Photography by David Ryle
Portrait photography by Olaf Blecker

Drax power station is the biggest in the UK. When you enter the enormous building, power is what you understand: you feel it, rather than see it.

In the pretty countryside surrounding Selby in North Yorkshire, it roars and rumbles and heaves. It is a giant storehouse of vibrations, from the high frequency of the turbines – 3,000 revolutions per minute, the same frequency as the 50Hz electricity it delivers – to the low, pulverising roll of the mills that grind the coal. It tastes of dust and iron filings. Blasts of hot, dry air from the six 4,000-tonne boilers bake the upper levels and steam hisses around lower gangways; warm yellow light casts shadows throughout. Rhomboid steel structures loom several storeys high, and metal pipes curve elegantly among the gaps. Drax is a megalith made from metal, but for all that power, it is vulnerable.

Martin Sloan, head of security at Drax, shows how. "That's the control unit," he says, pointing to a small grey box that feeds biomass into the mill. "If we weren't properly protected it would be vulnerable to cyberattack and could reduce the electricity output." Sloan is a powerfully built man with large brown eyes who used to run agents in Northern Ireland – often hiding them in his car boot – as a military intelligence officer. He shouts over the din, saying that he's "deaf from too many guns fired inside cars." After the Army, he spent eight years at MI5. "If we weren't properly protected, anyone in the world could theoretically get on that."

The central control room is quiet and pristine. It's full of bright plasma screens giving real-time read-outs of every pump and control unit in the power plant. The station can put out 3,960 MW, enough to boil more than two million kettles simultaneously. Another screen feeds in the demands from the national grid. Cameras show the fiery insides of the boiler. With its avocado carpet, the central control room has a 70s Bond-villain vibe. "All of the signals for measuring and controlling the plant are connected to PLCs [programmable logic controls]; whether it is a mill or turbine, the information comes in here," Sloan says. "Everything out there is connected."

Drax supplies eight per cent of the UK' s electricity and is one of the most advanced plants in the world. It is defined as part of our critical national infrastructure, which makes it attractive to hackers. "It's safe to say that the power industry as a whole has been the target of state-sponsored attacks," Sloan says. Industrial control systems are old hardware with old operating systems – sometimes a quarter of a century old. You can't patch them and you can't run antivirus on them. But they need to be connected to the outside world, whether that's the national grid sending its demands, or talking back to it to sell electricity at the right rates and to buy fuel at the right times. "The more that we connect the industrial control systems to the business IT, the more vulnerable we become," Sloan says.

The damage from an attack could be extremely serious. In 2014, malware shut down a German steel plant and wrecked its blast furnace. Stuxnet, which pushed back the Iranian nuclear programme by several years, was a digital weapon that entered through the enterprise side of the plant, made its way to the industrial side and caused centrifuges to run too quickly. HAVEX and BlackEnergy are two other pieces of malware dedicated to industrial control systems. "Loss of a PLC could result in serious damage to any operational process – even increasing the speed of a turbine; so systems are designed with hard-wired protection. However, this is our last line of defence and we would much rather be confident that our PLCs are secure," Sloan says. US Homeland Security says that industrial control systems were attacked 245 times in 2014. Admiral Michael Rogers, head of the US National Security Agency (NSA), in November 2014 warned that it was already possible for someone to shut down the entire US national grid via cyberattack.

Sloan is not alone as he walks through the turbines of Drax; he's accompanied by Dave Palmer, another former spook who spent more than a decade at GCHQ. Urbane and well spoken, with a quick smile, he is now director of technology at Darktrace, a cybersecurity startup that combines two things – advanced mathematics from Cambridge University and an operational staff drawn from the UK and US intelligence agencies. It's backed by Mike Lynch, the founder of Autonomy. Darktrace has been protecting Drax's enterprise networks since 2013; right now, Palmer and Sloan are developing a beta product to protect Drax's industrial control systems. Its job is not to keep attackers out. Because, according to Palmer, "they're already inside."

Early one morning in March, Mike Lynch is giving WIRED a history lesson in the offices of Invoke Capital, his venture-capital firm. Lynch looks like a bruiser made good: he has a big frame and bald head, but is today dressed as if he might be off to the Riviera, in a pressed white shirt, blue jacket and white trousers. He speaks with a slight lisp and with the zeal of a disciple. "Nothing is true," he proclaims. "Everything is probability."

The subject of today's lesson and the reason for these philosophic musings is the Reverend Thomas Bayes, a pious man who, in the 1730s, set out to prove the existence of God mathematically. Bayes's route to God was through probability, known then as "the doctrine of chances". "Bayes will probably turn out to be to the information age what Einstein was to physics," Lynch says.

In a paper published after his death in 1761, Bayes imagined a man "just brought forth into this world" and left to infer from his observations what was going on. He said that the Sun would probably engage his attention, but after it set on the first night, "he would be entirely ignorant whether he should ever see it again". But once it rose the next day, he might reasonably expect it to return a second time – maybe giving odds of three to one, Bayes wrote. When it did that, he would think the chances of a third sunrise even higher. Each sunrise is a new piece of information. And information changes the odds.

"The important thing about perception is it's totally subjective," Lynch says. "And so what you need is a mathematical bridge between all the methods that are objective we've developed and this subjective world, and Bayes's theorem gives you that."

Lynch is something of a Bayes enthusiast; he built a £7.4 billion business on his theorem. That statement is in itself a neat exercise in Bayesian probability: £7.4 billion is the price that HP paid for Autonomy in October 2011. HP later alleged that, because of fraudulent accounting, the business was worth nowhere near this and wrote billions off its value. It's now suing Lynch for

In November, Michael Rogers, the head of the NSA, warned it was already possible for a hacker to shut down the entire US national grid via cyberattack

CRITICAL ATTACK #1

NUCLEAR FACILITIES

Perhaps the best known physical-infrastructure hack, Stuxnet was a virus that attacked Iran's nuclear programme. It was probably smuggled into the system of the Natanz uranium-enrichment facility on a USB stick. Initially the work stayed dormant, analysing centrifuges. But in June 2010, it commandeered the machines and spun them until they melted down.

£3.4 billion in the UK courts; Lynch is countersuing HP for £100 million. The story is a fast-moving one and each visit to the lawyers adjusts the probability of what Autonomy was worth. As for HP, Lynch says: "I don't like them very much, I can tell you that."

Autonomy, which Lynch cofounded in 1996 in Cambridge, uses Bayesian techniques to analyse big data sets. "Bayes's theorem has been of interest to mathematicians for 250 years, but about ten years ago people realised that this was like a secret door in the wall," Lynch says. "The problem with Bayes is that you would need a supercomputer to do the calculations." Recursive Bayesian estimation – or a Bayes filter – is a mathematical short cut to perform those calculations. Many of these shortcuts were found by mathematicians at Cambridge University, and Lynch applied those equations to software. When data is messy and profuse, a Bayes filter offers a way of inferring what it probably means.

Autonomy is a Bayesian search engine. Regardless of how messy the business side of Autonomy has become, it was a pioneering business in machine learning – as Lynch puts it, "all the stuff you read about robots killing us all". Then he looks mock nervously to one side: "Any moment now, the Terminator is going to bash through the door and take us out."

For Lynch, machine learning is "the third revolution". The first was the replacement of muscle by machine in the industrial revolution. Then, in the mid-20th century, repetitive tasks such as payroll were replaced by computers (the word computer originally referred to the humans who calculated these problems). "Now you've got this revolution, which is replacing thoughtful tasks," Lynch says. IBM Watson is helping doctors diagnose disease; Google's cars are logging hundreds of thousands of kilometres by learning how to navigate in the real world; Netflix's algorithms learn your taste in films; City firms are using it to predict market movements and execute trades; Google's neural networks are learning what a cat is just by watching YouTube clips; Amazon, Microsoft and Google all have cloud-based machine-learning platforms that they offer to the world. Machine learning is the defining industry of the early 21st century.

After leaving HP acrimoniously (even before the various lawsuits), Lynch raised a $1 billion (£600 million) VC fund with an emphasis on operations – many of the partners at Invoke were part of the management team at Autonomy – and machine learning. Invoke's other companies are all in that category: Featurespace, which analyses behaviour to prevent fraud; Sophia Genetics, making sense of huge volumes of genetic data; and Neurence, a cloud-based machine-learning platform for object recognition ("Actually, that's the nearest thing to Skynet we're doing," Lynch grins). "With Invoke, first, we always like to bring a gun to a knife fight," Lynch says. "You always want the unfair advantage that the technology gives you. Second, we're only interested in things that can be really big and change the world."

Darktrace was Invoke's first investment – £12 million. To start with, it had little to do with cybersecurity. A spin-off from Cambridge University's Signal Processing and Communications Laboratory, which did ground breaking work on Bayesian statistical modelling, the idea was simple: use machines to learn about a company. The team then looked at where that approach could best be applied and settled on cybersecurity.

The result is literally a black box that is plugged into a company's network. The device then just watches, looking at how data flows around an organisation, mapping the network. That in itself is often useful. "You'll go to a customer and ask them how many devices they have on their network. They'll say, 7,000, maybe," says Nicole Eagan, CEO of Darktrace. "We'll put Darktrace in and we'll find 21,000 devices." The UI of Darktrace maps those data flows as beams of white light. "For many companies, this is the first time they actually see what happens inside their networks."

Darktrace doesn't look out for threats; it looks in. Eagan says: "Darktrace was this idea that cybersecurity needed to change." Its assumption is that every network is already compromised. "Our model is: you're not going to be fine. Now manage it," Lynch says. He adds that of the FTSE 100 companies that are clients, 80 per cent have found that someone else was in control of some aspect of their network. Darktrace doesn't think this is a problem.

"The idea is that you build some kind of wall," Lynch says, "and as long as you build it carefully enough, and you put a lock on every door and every window, you'll be safe."

Even the most technologically advanced wall has a flaw: the humans who guard it. "Last year's favourite one: take a CD-ROM, you write '2013 salary review' on it and you leave it in the car park," Lynch says. "That has a greater than 90 per cent chance of getting installed on to the network." Jim Penrose, a former NSA staffer and the executive vice president of cyber

The control room at Drax: every industrial control unit, the plant's electricity output and temperature are all monitored in real time

Drax power station, in Yorkshire, supplies eight per cent of the UK's electricity. Its 3,960 MW capacity is enough to boil two million kettles at once

intelligence at Darktrace, wistfully describes it as "the frailty of humans trying to get their job done".

Lynch borrows an analogy from the immune system. "You have about two kilos of bacteria in you, and your DNA has lots of bits of viral DNA in it," he says. "Your bacteria in your throat, as long as they don't do anything they shouldn't, that's cool. As soon as they do something bad, your immune system goes for it." The "central genius" of the immune system, according to Lynch, is that, in the womb, it learns what is you. So when something else does something that isn't you, it spots it. "Being infiltrated is business as usual," Lynch says. "And just like we walk around and catch colds, the issue is not catching colds, the issue is not dying of flu."

In practice, it means this: if a company computer is connecting to one in Kyrgyzstan, or shipping a four-gigabyte file internally, that could be suspicious. It could also be because a salesperson has a contact in Kyrgyzstan, or a video editor is moving a film over the network. According to the company, Darktrace can tell the difference. When it notices something suspicious, the streams of white light on the UI turn yellow or red. A human can then ask the machine why the behaviour is a concern.

During a demo in Pall Mall, Palmer and Penrose show an example. "So this computer is talking to significantly more devices at once than it normally does. It's attempting to talk to a number of devices that are refusing to talk back, suggesting it's not meant to be talking to them at all. And there's been a surge in the amount of internal data that it's drawing down from the rest of the network."

That alert popped up after 40 seconds of unusual activity and is a relatively blunt attack. A skilled hacker might keep quiet for months, slowly scoping the network for weaknesses. But Darktrace says it can detect that too. "Even though someone's trying to hide themselves in your network, they have to try and do something," Penrose says. "Just chilling there and doing nothing isn't helping them. They have to strike to get to their objective. And as soon as they strike, it's: hey, what's that?"

The word activity is important. The way much antivirus software works is by matching malware against known descriptions of it, or signatures. The piece of malware that Palmer has found has no signature, because it was created as a bespoke test. It got through the test bed antivirus software, but Darktrace spotted it. It can look for problems you can't think of and which haven't even been identified before.

Dave Palmer spent 11 years at GCHQ before joining Darktrace as director of technology

"Some of the major stuff that goes on in some of the biggest companies in the world – just jaw-dropping," Palmer says. Installed on a large bank's network, Darktrace says it discovered a huge Bitcoin mining rig running on the bank's servers. Elsewhere there was an underground Asian internet gambling group embedded inside a US company. In another company, Darktrace discovered an error in the backup server which meant that anyone could read the archived emails of any other employee – and lots of people were taking the chance to do so. Palmer found that the passwords protecting some parts of the UK's privately owned critical national infrastructure were the company's name, followed by "uk1". Penrose claims that Darktrace would have spotted Edward Snowden before he leaked.

"Nobody's really, I think, using the same kind of unsupervised machine-learning techniques we're using in combination with their Bayesian estimations," Penrose says. "We're substantially ahead of the pack."

In UK technology, spies are the earliest adopters. We've never had a cybersecurity industry to compare with those of the US or Israel (or even Italy, for that matter, which for some reason has a nice line in creepy spyware companies such as Area SpA, Hacking Team and IPS), but government agencies have been world leaders since the invention of the telegraph. The British Empire controlled global signal traffic through the All Red Line, a worldwide network of electrical telegraphs, even annexing a random island in the middle of the Pacific in 1888 for total coverage. That forced other nations to start encrypting their traffic, so codebreaking became a focus.

During the first world war, Room 40 of the Old Admiralty Building in Whitehall was the home of British cryptanalysis, decoding around 15,000 German messages, including telegraph traffic. After the war, the government established the Government Code and Cypher School to track and decipher diplomatic cables. In August 1939, just before the German invasion of

PHOTOGRAPHY: REX

CRITICAL ATTACK #2

TRANSPORTATION
In 2008, a tram driver in Lodz, Poland, attempted to turn right, only for his vehicle to swerve left and derail. Similar accidents occurred throughout the city, with four derailments and over 20 people injured. Authorities discovered that it was the work of a schoolboy who had built an infrared "remote" to move the tracks and use Lodz's trams as a personal train set.

Poland, it moved to Bletchley Park, expanding its staff to 10,000 by recruiting lecturers from Cambridge and Oxford, and changed its name to Government Communications Headquarters. Winston Churchill called GCHQ the "geese that laid the golden eggs but never cackled". The organisation maintained that tradition of technological savvy and secrecy – public key cryptography was invented by a GCHQ employee in 1970, but this fact was kept secret until 1997 – right up to the Snowden leaks.

"The fact is we've got a long heritage of strong capability in cybersecurity in the UK, dating from the first world war," says Alex van Someren, a partner at Amadeus Capital and the author of a classified report on cybersecurity commissioned by the UK government. "We've been developing codes and ciphers for secret communications in the UK for a very long time. But the same techniques that can be used to defend our national infrastructure or protect our national secrets are just as relevant to mom-and-pop stores on the internet or big financial services institutions in Canary Wharf."

Winston Churchill described the Government Communications Headquarters – GCHQ – as the 'geese that laid the golden eggs but never cackled'

CRITICAL ATTACK #3

WASTE MANAGEMENT
Disgruntled after his job application for the local council was rejected, Vitek Boden waged war on the computerised waste-management system of Maroochy Shire, Australia. The hacks, in 2000, resulted in the spillage of tonnes of raw sewage into the shire's parks and rivers, killing much aquatic life.

Darktrace started working with GCHQ and MI5 very early on. Lynch's very first company, Cambridge Neuro-dynamics, had done work for the British intelligence agencies; as Lynch told WIRED US in 2002, "they have the most interesting problems". Steve Huxter, an ex-MI5 man, was a Darktrace co-founder. Andrew France, deputy director for cyberdefence at GCHQ, was poached as CEO. Sir Jonathan Evans (now Lord Evans of Weardale), a former director general of MI5 who memorably argued that intelligence obtained through torture "had to be seen in the context of the times", became an adviser to the board. There were other hires from GCHQ, MI5 and the NSA; Darktrace was building some impeccable cyberspook credentials. "A combination of maths from Cambridge with the credibility of GCHQ and MI5 is unmatched," says Eagan, who took over from France as CEO of Darktrace.

MIKE LYNCH
THE GATEKEEPER

Born in 1965, Mike Lynch grew up in Chelmsford, Essex, where his mother was a nurse and his father a firefighter. He won a scholarship to Bancroft's School in Woodford, and went on to read natural sciences at Christ's College, Cambridge, where he was also awarded a PhD in mathematical computing and a research fellowship. He first entered technology in the late 80s, founding Lynett Systems, a software company catering for the music sector. But it was Cambridge Neurodynamics – which he set up in 1991 with a loan from a philanthropist – that catapulted Lynch to tech stardom. The company specialised in the computerised recognition of fingerprints, bringing down the time it took to make a positive ID from three weeks to just five minutes.

In 1996, Lynch founded Autonomy with South African mathematician Richard Gaunt. Originally a spin-off of Cambridge Neurodynamics, Autonomy had a mission: to harness Bayesian statistics to create software that could analyse and understand unstructured data to extract relevant pieces of information. Within four years, Autonomy was a £3 billion company and was floated on the London Stock Exchange in November 2000.

Over the following years, Autonomy was one of the leading lights of British tech innovation, becoming Britain's largest software company by 2010. Lynch, who prefers to keep a low profile, was awarded an OBE – the press described him as "Britain's Bill Gates" and "The King of Silicon Fen". In October 2011, Hewlett-Packard acquired Autonomy for $11.7 billion (£7.5 billion). Lynch would subsequently work for HP for less than a year, eventually resigning in May 2012. A few months after his departure, HP accused him of cooking Autonomy's books and inflating the firm's value by almost three-quarters ahead of the deal. Lynch denied the allegations. The controversy resulted in transatlantic litigation: HP sued Lynch for $5.1 billion and the entrepreneur counter-sued with a $150 million (£100 million) lawsuit. An investigation into Autonomy's sale by the UK's Serious Fraud Office concluded in January 2015 there was no evidence to support HP's case. But the dispute continues in the United States. GV

Mike Lynch photographed in 2000, the year that Autonomy went public

Names such as Evans's certainly helped, but whispers about Darktrace's technology were the biggest enticement for security officials. Jim Penrose joined the NSA in 1997 – "when it was in low-profile mode" – and worked in cyberexploitation, that is, supporting counterterrorism operations with digital espionage. He heard about Darktrace through contacts at GCHQ and started to try and find out if the product did everything it promised. "And I convinced myself that, yeah, it does, and that's pretty cool," he says. "I thought, this is going to be a game changer for the cybersecurity industry."

"It's not radical and it's not new," Ross Anderson says. "The idea that you do data mining on network traces is an old one." Anderson is professor of security engineering at Cambridge University, a fellow of the Royal Society and was a friend of the late Bill Fitzgerald, out of whose lab Darktrace emerged; they played Irish pipes together. "If what's happened is a startup that's trying to produce a British dog in this fight, then good luck to them. But this is an established business." Mark Hughes is head of security for BT, which is a (happy) Darktrace customer. But even he says that "using Bayesian logic is not anything brand new". Bruce Schneier, who is probably the leading security commentator in the world, says: "This whole notion of behavioural detection is something that a lot of research has been put into, there's a lot of stuff out there, there's a lot of people doing a lot of things. There's a lot of snake oil around; be really careful.

"This is the kind of thing where you need a PhD in the field and you might have to spend 80 to 100 hours figuring out how new it is, how important it is... This is the problem. There's nothing you can ask. How do you know if they're lying?"

Writing about cybersecurity is a very unmathematical exercise in Bayesian estimation; weighing up various pieces of information to come up with a probabilistic – and always uncertain – verdict on a technology.

So let's add more information to the mix and see how the probability, the doctrine of chance, changes.

Darktrace draws many of its employees from the ranks of the UK security services. However, the Snowden revelations about GCHQ's reach are not a guarantee of its quality. As Anderson puts it, "They've got one or two capable people but they have also produced crap in the past as well." A government insider, who works on technical issues and who wishes to remain anonymous, tells WIRED: "You have to bear in mind GCHQ is just another part of the Civil Service and so it is as competent and as good and as bad, as, for example, the Department for Work and Pensions. They certainly do have some sharp folks but the best crypto minds are often now in high-tech companies actively working to stop them snooping on their customers." GCHQ also presents another problem for a cybersecurity company: "There's an enormous conflict of interest," Schneier explains. "The NSA and GCHQ are in the business of ensuring everybody is insecure."

Even if they are technically very capable, spooks may not be suited to the private sector. Co-founder and ex-spook Huxter has been quietly scrubbed from the company's literature; he didn't survive the transition from startup to bigger company, leaving in 2014. So too Andrew France, who swapped decades of service at Cheltenham to join Darktrace, but left after less than a year. He told *The Wall Street Journal*: "It needs now a different kind of strategic leadership that's not me." But someone who knows France well says that he didn't enjoy the Invoke Capital experience and quickly determined to leave, playing nice to avoid the wrath of Lynch's lawyers. (France did not respond to requests for an interview.)

Nor is the idea that cybersecurity should no longer be about building walls unique to Darktrace. Alastair Paterson, the CEO of Digital Shadows, a UK threat-intelligence company, says: "Five years ago security was all about the perimeter – keeping your data in the middle and building the walls higher and higher around the edges. Today's world is no longer like that... There are many approaches out there." Van Someren says: "It's widely accepted in the industry that the idea that one can build a robust perimeter is no longer a meaningful concept... Some of these smaller businesses have technology that is at least as interesting [as Darktrace's]."

Darktrace's black box necessarily remains a black box. But its customers can add more information to the Bayesian estimation, and they're positive about the technology. BT's Hughes says: "The things that characterise Darktrace specifically are the robustness of the algorithm. The maths behind it seems to work – from our experience it's certainly finding things that other things aren't." He wants to integrate it further into BT, which manages most of the UK's internet infrastructure. "We saw it as being complementary for the many other tools that are out there."

"Irrespective of what a salesman may tell you about how good the product is, it is results that count," Sloan says. "There's no denying the benefit that Darktrace delivers. It is not about being able to shut all the doors, as someone will always leave one open – whether it is an infected USB stick or software drive-by vulnerability. What matters is your ability to identify a breach once it has happened."

Darktrace is adding more customers, with 75 so far, and is building out its sales operations worldwide, especially in Asia. In March, it raised another £12 million, from Invoke, Talis and Hoxton ventures, at a valuation of £54 million. It's tweaking its product for new sectors, including industrial control units and the internet of things. "What's unique about the maths of machine learning is that it's largely extensible," Eagan says. "You just tweak the maths models."

"Darktrace is a fundamentally different thing and I think it's going to very valuable," Lynch says. "The only issue at the moment with the sector is that it's very noisy. You just have to cut through that noise."

'Five years ago, security was all about the perimeter – building the wall around your data higher and higher. Today's world is no longer like that' – *Alastair Paterson, CEO Digital Shadows*

On a wet Wednesday evening in April, WIRED attends the launch of a new startup incubator in Hammersmith. Pink Champagne is served in the co-working space, which has the affectedly tasteful homeliness of a members' club tempered with the blandness of a smart airport lounge.

CRITICAL ATTACK #4

AIRCRAFT
The founder of cybersecurity company One World Labs, Chris Roberts, grabbed headlines – and the attention of the FBI – when he claimed he'd hacked, via in-flight entertainment systems, the computers of various aircraft, causing them to move laterally and to climb.

CRITICAL ATTACK #5

TRAFFIC-MANAGEMENT SYSTEMS
During a union protest in 2006, two traffic engineers in Los Angeles used a laptop to remotely access the city's traffic system and alter the light sequences. The hackers, Kartik Patel and Gabriel Murillo, wrought havoc on four key LA intersections, making sure that the red lights became virtually endless. The ensuing gridlock lasted several days. **Gian Volpicelli**

Drax burns coal, but will switch to biomass, enabling a 12m-tonne cut in carbon emissions

The crowd isn't much different from that of any other incubator launch, but there are a few people dressed neatly in smart casual and sporting crew cuts. And it's not an investor or an entrepreneur opening the space, but Iain Lobban, the former director of GCHQ, in charge from 2008 to 2014 (interesting years for the agency).

This is CyLon, the first UK incubator dedicated to cybersecurity. Set up by Alex van Someren and Epsilon Advisory Partners, it currently hosts eight companies. In a speech, Lobban good-naturedly paints a worrying picture for the invited audience in west London: "Cyber is constantly evolving, it is constantly outstripping nations' efforts... The actors are multifarious. Intelligence agencies – allegedly. Criminals who are approaching levels of sophistication and organisation that state actors would be proud of, industrial espionage, hackers for hire, hacktivists. And the threat increases where there's overlap between the groups, where we see intelligence agents conducting industrial espionage, with or without their governments' approval, cybercriminals who may be or enjoy intimate links with government intelligence actors, state-affiliated groups or patriotic hackers acting on a deniable basis to serve nefarious aims in their national interests."

But that challenge also offers possibility, Lobban argues, for innovators. Hence, CyLon, "a great example of how we can identify, nurture and apply the creativity that is exploding in the UK cybersecurity sector," he says, loftily comparing the incubator to the legendary Bletchley Park. Afterwards, he speaks to WIRED, referencing Churchill: "I hope to see a few golden eggs laid here."

It's boom time, for the first time, for UK cybersecurity startups – not just Darktrace. Companies such as Digital Shadows, Ripjar, Cyberlytic, Intercede, Garrison Technology and Surevine make up a new wave of nimble companies challenging the new guard. According to the Department for Business, Innovation and Skills, the UK cybersecurity sector is worth £6 billion; customers worldwide spent £1 billion on UK cyberproducts in 2013, an increase of 22 per cent from the previous year; in 2016 the UK total is predicted to rise to £2 billion. In January, David Cameron accompanied those companies and others (including Darktrace) on a trade mission to Washington.

"I do think that this is actually a real renaissance time for cybersecurity here in the UK," van Someren says. These companies may not replace the giants of the security world – Symantec, FireEye, Palo Alto Networks, Kaspersky Lab, Check Point, Fortinet – but startups can be more agile than these billion-dollar-plus incumbents. As Eugene Kaspersky, founder of the world's largest privately held retailer of software security products, tells WIRED: "Startups are a very good thing, and it's always essential to keep on looking for new approaches to tackling cyberthreats, simply because they evolve so fast. The market is constantly evolving, there are new companies emerging, they challenge the bigger ones, and the latter fight back."

What's behind the UK boom? Funding is certainly one aspect. High-profile hacks, such as those perpetrated against Sony and Target, mean customers are willing to spend more on cybersecurity, so in turn, investors are more willing to fund new companies to sell to them. But although that benefits the UK, it's a global trend. Eagan suggests films such as *The Imitation Game* and *The Theory of Everything*, which celebrate British code-breaking and boffinry, have helped. She also cites the Bond movies.

Really, though, what we're seeing is the self-privatisation of GCHQ. "The UK has some great talent in the cybersecurity space, many of it developed in the government agencies and their supporting industry partners before spinning out new companies," Paterson says. According to van Someren, "There has been a trend for both people and technology to transfer from the defence and intelligence world into the commercial world." If there's no such things as bad publicity, then Edward Snowden did a lot to raise the agency's profile, and staffers are cashing in. The starting salary at GCHQ is £25,500 and the rewards in the private sector are far greater, thanks to investors' money.

And that's good for GCHQ, too. "Government is absolutely reliant on the innovation and dynamism that is out in the public sector," Lobban proclaims at the CyLon launch. There, WIRED bumps into Tom Griffin, the CEO of Ripjar, which mines social media in real time, and is another GCHQ alumnus. Ripjar came out of the first joint open call for new technologies from MI5 and GCHQ. "If I was ever going to leave GCHQ it would have been to do my own thing." He says that when Andrew France left GCHQ for Darktrace, "it caused a bit of a stir". But Griffin, who spent eight years at Cheltenham, left soon after, along with four other GCHQ colleagues, in October 2013, around the same time as the Darktrace exodus. "There are people at the top of GCHQ who see the big picture, the benefits that moving technical talent to the private sector can bring," Griffin says. "They know we can develop software and push things at a very fast rate. And the sorts of technologies that we're pushing are the sorts of technologies that are always going to be useful for an organisation like that."

Darktrace is part of this and certainly one of the leading companies in the scene. Is the technology radically new? A game changer for cybersecurity, as it argues? It's another security tool that increases the odds. Any definitive statement is unwise. To borrow from Lynch: nothing is true, everything is probability – the doctrine of chances. ■

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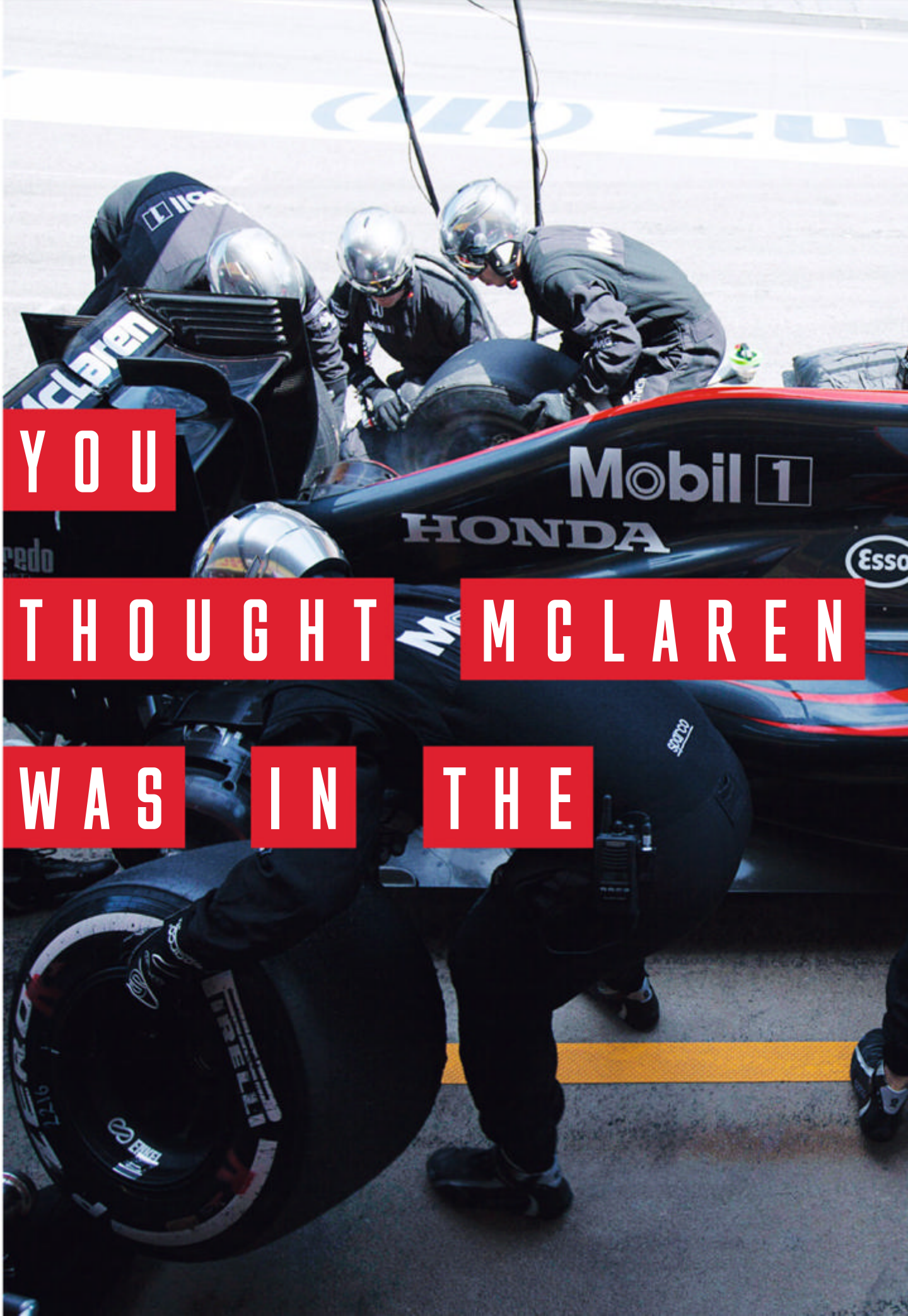

YOU THOUGHT MCLAREN WAS IN THE

CAR BUSINESS

The McLaren pit crew work on Jenson Button's car at the Spanish Formula 1 Grand Prix, May 2015

SO WHAT'S IT DOING IN

The McLaren-optimised Aquafresh production line at GlaxoSmithKline's Maidenhead factory

A TOOTHPASTE FACTORY?

Sometimes a business needs to discover its true value. At McLaren, that has meant branching out from F1 to health trackers, Olympic bikes... and an Aquafresh factory

By **João Medeiros** Photography: **Greg White**

McLaren's Geoff McGrath at the company's components lab

ONE MORNING IN MARCH 2012, GlaxoSmithKline engineer Shaun Glover visited the McLaren Technology Group headquarters in Woking, Surrey. A year earlier, McLaren's CEO and founder Ron Dennis and Andrew Witty, the CEO of GlaxoSmithKline (GSK), had signed a partnership deal. "There was an internal call for proposals, so we put ourselves forward," says Glover, who is the engineering director of a toothpaste factory in Maidenhead, the biggest of its kind in Europe. It makes products for brands including Sensodyne, Aquafresh and Macleans, 400 million tubes every year. "Some of us connected the dots about how a Formula 1 team would be able to help us. Of course, others questioned what a Formula 1 team could ever know about making toothpaste."

That day, Glover and his team met Geoff McGrath of McLaren Applied Technologies (MAT), a company set up in 2004 by Dennis to apply Formula 1's high-performance culture and working methods to businesses such as GSK. McLaren's headquarters is the 57,000m² Foster + Partners-designed McLaren Technology Centre, which embodies the ethos of one of the oldest and most successful teams in the history of Formula 1 racing. Its glass-fronted main building combines with an artificial lake to form a yin-yang shape. The roof is self-cleaning, using a drainage system to collect rainwater and refill a lake which, in turn, helps regulate the internal temperature. The building is connected to the nearby production centre, where McLaren Automotive makes its luxury sports cars. Technicians in lab coats and gloves carefully assemble F1 cars in pristine workshops. All desks are free of clutter, food and drink, according to strict rules imposed by Dennis that also forbid exposed pipes and cables anywhere in the complex.

LEARNING THE McLAREN WAY

UNIVERSITY OF OXFORD

In March 2015, McLaren signed a three-year partnership with the University of Oxford to build a surgical simulator to help train new surgeons. It will also develop monitors to verify patients for surgery and the effectiveness of the procedure.

TO INTRODUCE HIS GUESTS TO McLaren's high-performance culture, McGrath played them TV footage from the 2008 Monaco Grand Prix. In heavy rain, team driver Lewis Hamilton hit a barrier on lap six and punctured a tyre, forcing him to make a pit stop. Throughout the incident, the TV commentator is animated and loud. Monaco is a notoriously difficult circuit. This was surely game over for Hamilton.

McGrath then played the exact same clip, this time accompanied by the McLaren internal audio feed. Immediately after hitting the wall, Hamilton is given precise instructions by his race engineer: "Lewis, you're coming into the pit, you make a change to the steering, the launch switch, make sure you've done that, you're going to get new tyres and you're going to get fuel." Then, in contrast to the TV commentary, there's silence. Shortly after, McLaren's chief mechanic says: "Bail out" – fuel the car until the end of the race because there will be no more pit stops – and "Tyre set 22," a pre-determined set of intermediate tyres. More silence. Hamilton's pit stop lasts nine seconds. When Hamilton exits the pit lane he is

SPOT ILLUSTRATIONS: TOMI UM
PHOTOGRAPHY (OPENING SPREAD): REX

told the identity of the drivers behind and in front of him. Nothing else.

"Before the race starts we know what we will do if the tyres degrade more quickly or slowly than we think, if our competitors are slightly faster than we thought, if the safety car comes out," says Andy Latham, a former race engineer at McLaren who is now chief engineer of analytics at MAT. "We will have a pre-determined plan for any possible scenario. We evolve those plans during the race. The last thing I want is to have to make tough decisions during the heat of the race."

The moment Hamilton hit the barrier, all 13 members of McLaren's pit crew knew what to do. He went on to win the race – and the drivers' championship.

McGrath and his team had visited the toothpaste factory in Maidenhead in November 2011. After studying the factory's working methods, they figured out that a production-line bottleneck was occurring during the so-called changeover: transition periods when factory workers needed to switch products on the line from one toothpaste brand to another. This meant changing and cleaning the tubes,

'If we can change four tyres on a Formula 1 car in two seconds, why does it take us two hours to do a changeover in the toothpaste factory?'

GEOFF McGRATH

McLaren engineer Caroline Hargrove in the Formula 1 simulation room

LEARNING THE McLAREN WAY

GLAXO-SMITHKLINE

MAT helped to increase GSK's toothpaste production at its Maidenhead factory by 20 million tubes a year. The companies are now working together on real-time patient assessment. They have completed a trial phase with stroke patients and people suffering from arthritis, using sensors placed on the nape of the patient's neck to monitor mobility.

‘We will have a pre-determined plan for any possible scenario’

ANDY LATHAM

rearranging the tools in the line and a number of other procedures that halted production. For McGrath, the similarities with F1 pit stops were obvious. “If I can change four tyres on a car in two seconds,” he questioned, “why does it take me two hours to do a changeover in the toothpaste factory?”

McGrath started discussing production with the factory managers and shop-floor workers. Was the tooling standardised? Were they demonstrating a sense of pride in their work? Was there a belief system in the factory? Was the changeover team specially picked or just whoever is available at the time? Armed with answers, the McLaren team made a computer model of the production line, which allowed them to simulate and visualise the process, much in the way it does for F1 races.

“We didn’t tell the shop-floor workers what to do,” McGrath says. “We put them in McLaren overalls and let them play with the system. They saw for themselves what had to change.” The Maidenhead team developed a seven-step process that began before the changeover, mirroring McLaren’s cycle of simulation, pre-planning, debriefing and continuous improvement. Changeover times fell by 60 per cent, dropping from an average of 39 minutes to 15, equating to an extra 20 million tubes by the end of the year. “We used to see changeovers as down time,” Glover says. “McLaren sees pit stops as an opportunity to win the race.”

LEARNING THE McLAREN WAY

KPMG

In November 2014, MAT signed a ten-year partnership with the audit firm. It will provide predictive analytics to develop models, based on real-time market data, which are built to be forward-looking, rather than reactive.

ELEVEN YEARS SINCE ITS LAUNCH, MAT has become McLaren’s fastest growing and most profitable company: in 2013 McLaren Group group generated £268 million in revenues (of which McGrath says MAT contributed “tens of millions”), despite the recent poor performances of its racing team. Among its other projects, MAT has designed health-monitoring systems for stroke victims and amyotrophic lateral sclerosis patients based on F1 telemetry; created a scheduling system for Heathrow Airport that reduces flight delays; and worked with some of the world’s biggest oil and gas companies, pharmaceutical conglomerates, data-centre operators and sports brands. McLaren has transitioned into a technology group that happens to have a successful F1 team.

MAT didn’t make any money in its first five years. In fact, it didn’t make much of anything. When McGrath, a mechanical engineer who previously worked in oil, gas and telecommunications, joined MAT in October 2009 to become its vice president, the company consisted of himself; Steve Rose, a software engineer; and an engineer called Caroline Hargrove. Hargrove had worked for McLaren’s F1 team since 1997. She played a key role in designing and building F1’s first racing simulators.

Today, McLaren has two simulators at its headquarters: one sits in the basement, near a 145-metre wind tunnel; the other in the area above, where McLaren’s racing cars are built. They are similar: full-size car chassis mounted on a dynamic rig surrounded by 180° curving video screens, with a motion system that reproduces the g-forces generated in an F1 race. A one-way mirror separates them from a control room with five desktop computers and a flatscreen that can display in real time hundreds of parameters extracted from the simulator, such as the angle of the steering wheel, the speed the car wheels are turning, acceleration and engine revs. Team and test drivers spend about 180 days a year inside the simulator – seven times more than in an actual car. They arrive for a session before each race and a debriefing after. The engineers don’t usually give them any data – most sessions are blind tests.

“The simulator represents everything we think we understand about the car,” Hargrove says. “There may be discrepancies between our model and reality – the drivers are our filter. They take in vast amounts of information and can pick out anomalies. We often use the driver for that purpose when we are unsure what’s going on. If the driver says, ‘Yes, that feels exactly like the track,’ you know that your model is right.”

The Vehicle Dynamics Simulator can be tailored to the needs of other carmakers

During a typical F1 season, McLaren might change up to 70 per cent of a car’s mechanical components. It used to build these parts before testing them on the track, but season testing was banned by the sport’s governing body FIA in 2007 to cut costs. Suddenly, teams with a simulator had a major technological advantage. By then, McLaren was already modelling and testing the components virtually, before using the simulator to test the effect each new component had on the driver. Today, every component is tested, in its virtual form, in the simulator.

“Let’s say you want to test a new anti-roll bar,” says Hargrove. “We could build a prototype model, put it inside your car and test it on the road – or we could build a virtual model and test it on the simulator. We know the size, the specs, how it behaves with physics. The program computes how the new component interacts with every other component in the model. That data is fed to the simulator, where the driver then tests it.”

In the weeks leading up to a race, McLaren builds a detailed computer model of the circuit and the performance of all the other cars in the race. This computer model allows engineers to simulate any possible scenario and predict its outcome. The team

Duncan Bradley adjusts a Datarider sensor under a Specialized saddle

runs millions of simulations, running through all possible permutations and variables, such as timings for pit stops, numbers of pit stops, types of tyres and safety cars. McLaren calls this a decision-support system: for every scenario, the computer helps the team to pick a strategy that will result in a positive outcome.

During the race, the McLaren team continues to run simulations from its headquarters, updating the models with live timing data and telemetry from the car, performing tens of thousands of new simulations for every lap.

"The racing car is the perfect intelligent product," McGrath says. "It's continuously improved upon with extreme time pressure and is custom-built to an individual consumer, the driver. We design it in the simulator and leave the telemetry in the product for remote condition monitoring. That intelligence tells us how the product is being used." To McGrath, the data coming off the physical product is worth more than the product itself. He calls it the metaproduct.

"When we started we were basically three people sitting at a table, wondering how to build this business," McGrath says. They were trying to answer the question: what would McLaren do if it didn't make F1 cars? McGrath had a plan, at least in theory. It was a vision that intersected with Hargrove's simulators and computer models, the telemetry in the race cars and the data design of the prototypes. This is what they could offer to businesses that were traditionally managed retroactively by studying quarterly financial reports – data from the past. McLaren would get them to work with live data, to compete in real time and to simulate the future.

LEARNING THE McLAREN WAY

SPECIALIZED

In 2014, MAT and bike firm Specialized released the successor to the Venge. The S-Works McLaren Tarmac is the result of a two-and-a-half-year project in which MAT collected data from riders and extensively simulated the bicycle's movement.

SCOTT DRAWER WAS HEAD OF RESEARCH and innovation at UK Sport at the time of the GSK project. He enquired whether McLaren and Team GB could collaborate in preparation for the 2012 Olympics in London. Drawer was an F1 fan and he wanted to bring some of its practices, such as telemetry and predictive algorithms, to other elite sports. The two organisations began to collaborate on disciplines that involved interaction between athlete and machine: cycling, sailing, rowing and canoeing.

"Track cycling was particularly successful," Hargrove says. "Of all the Olympic sports, it's probably the most akin to F1 except that, instead of an engine, they have a person." Drawer wanted to understand the correlations between power, cadence and heart rate and how those parameters translated to results on the track, but the cycling team didn't have enough data points for the sprinters. So McLaren built the Datarider, a small aerodynamic box which nestles under the rider's saddle and connects to sensors in the bike to collect data related to power, torque and bike angle. The device itself contained accelerometers, gyroscopes and Bluetooth transmitters. Previous sensors used by the cycling team could transmit information at a frequency of approximately 20Hz. Datarider had 200Hz. (The sensors used in F1 run at 1,000Hz.)

"I wanted to make sure everything was calibrated perfectly so we did all the testing on our site," Hargrove says. "I saw the data from [track cyclist] Chris Hoy, panicked and rang them to apologise. It seemed obvious that I had the calibration wrong as the numbers were so high. They said it was fine – those were the numbers Hoy produced."

By 2010, McLaren was seeking a partnership to design a bike. It contacted the third-largest bicycle brand in the world, California-based Specialized Bicycle Components. "We wanted to apply data-driven design to make a bike," says Duncan Bradley, head of high-performance design at MAT. "Like any other bike maker, Specialized would design by eye. Test riders would then ride the bike and give subjective feedback. That's exactly how we would design F1 cars 50 years ago."

Specialized's brief to McLaren was to make a lighter bicycle, under the assumption that it would then be able to travel faster. McLaren started by questioning that assumption. "On a bike, you've got a stiff structure – the frame – with a heavy bag of water, the rider, sitting on it," Bradley says. "We had to consider the human aspect of the movement. How do you maximise the equipment performance with a human in the loop? In this case, it was more: how do you maximise human performance with equipment in the loop?"

McLaren started by studying the frame, attaching more than 20 sensors that could measure the various forces and vibrations that affect a moving bike and the way people ride it. They adapted the chassis rig of Hargrove's driving simulator to fit on a bike. Once they understood how it moved, they applied the same forces to a test rider – in this case Bradley, a keen cyclist. One element at a time – the frame, the tyres, the human – they developed a formula that crystallised their understanding of how people ride bikes. "With that computer model, we could specify whatever parameters we wanted – shape, weight, stiffness – and design quickly," Bradley says. "We completely flipped the way bikes were designed."

It took eight months to design the bicycle, the S-Works + McLaren Venge, which came out in 2011. It was 20 per cent lighter than Specialized's previous top model, the S-Works, but had the same structural stiffness. The same year, Mark Cavendish won the UCI Road World Championships – the first British rider do so since 1965 – riding a Venge.

"Specialized later told me that they had learned more in six months about bike design than they had in the previous ten years," McGrath says. "They also told me that we didn't charge enough."

LEARNING THE McLAREN WAY

TEAM GB

MAT provided telemetry and simulation based on F 1 technology to help Team GB win gold in Women's Skeleton at the 2014 Winter Olympics. For the 2012 Olympics, the team helped British Cycling by making the Datarider data recorder.

THE 2011 GSK PROJECT ENABLED MAT TO enter the healthcare market. Two years later, McLaren provided monitoring sensors for a GSK clinical trial with 100 stroke patients in the UK and US. McLaren had previously tested the sensors on rugby players, measuring data during training and developing algorithms that could predict when a player would peak in training and when they'd run the risk of injury.

"Most wearables can only tell you how many steps you've taken, not how many hours you spend sitting or lying down," McGrath says. "They lack contextual awareness, which is what you need for clinical trials. I would even question that the wrist is the best place to get any kind of insight – the upper body is far more useful."

That sort of insight was exactly what GSK needed. One of the ways to measure a stroke patient's health and response to medication is to assess their mobility. "Once every month or so we would ask a patient to walk between two chairs ten metres apart, and see how many steps they take and how long it takes them," Julian Jenkins, GSK's vice-president of project planning and management, says. "I don't know how long it takes for me to walk ten metres, let alone a stroke patient. It was flawed."

McLaren placed a device the size of a ten-pence piece on the patients' necks to measure 20 parameters such as gait, cadence and stride frequency. "When I saw the first patient's data I was astonished," Jenkins says. "Within seconds, I could tell that the patient was very sick. There's no test that we could have done before that would reach the same conclusion. I realised then that this was going to change clinical trials."

GSK and McLaren are now conducting clinical trials with amyotrophic lateral sclerosis patients and, in March 2015, McLaren announced a partnership with the University of Oxford, with the aim of using analytics to improve patient care and to build a simulator for surgeons.

"Humans are hard to model," McGrath says. "But we always thought that if we can measure the health and condition of an engine, why can't we measure the health and condition of a person?" W

João Medeiros is science editor at WIRED. *He curated the annual* WIRED *Health event in April*

'We have completely flipped the way bikes are designed'

DUNCAN BRADLEY

LEARNING THE McLAREN WAY

HEATHROW AIRPORT

MAT worked with National Air Traffic Services to improve the efficiency of Heathrow's ground traffic by decreasing the amount of time aeroplanes spent circling the airport and optimising their arrival and departure times. Thanks to the new system, the London airport could accommodate a new daily service from Vietnam Airlines.

BOY, INTERRUPTED

PHOTOGRAPHY: ELINOR CARUCCI

BY FRED VOGELSTEIN

THIS IS SAM.

HE'S MY SON. HIS EPILEPSY CAUSED HIM TO HAVE UP TO 100 SEIZURES A DAY. AFTER SEVEN YEARS WE WERE OUT OF OPTIONS. OUR LAST HOPE: AN UNTESTED, UNPROVEN TREATMENT. THE ONLY PROBLEM?

IT WAS ILLEGAL.

THE

hospital pharmacist slid three bottles of pills across the counter, gave my wife Evelyn a form to sign and reminded her that this was not a high-street chemist. The pharmacist made it clear that he would be in touch with our doctor and the company supplying the medication. They would find out if she broke the rules.

Evelyn slipped the bottles into her purse. She and our 11-year-old son, Sam, were jet-lagged. They'd flown from San Francisco to London the previous day, December 19, 2012. It was just after 7pm. They'd been at Great Ormond Street Hospital since mid-morning. Sam had been through a brainwave scan, a blood test and a doctor examination.

Evelyn was terrified. They'd travelled 8,600km to get these pills, medicine we hoped might finally quiet Sam's unremitting seizures. He was to take a 50-milligram pill once a day for two days, increasing the dose to maybe three pills twice a day. They would need to revisit the hospital two more times before they returned to San Francisco on January 3, 2013. That meant two more rounds of brain scans, blood tests and doctors' appointments.

We were confident the medicine wouldn't kill or hurt Sam irreversibly, but the prospect still made us nervous. The pills contained a pharmaceutical derivative of cannabis. People have been smoking cannabis medicinally for thousands of years. Deaths are rare. But Sam would get a specific compound made in a lab. The compound, cannabidiol (CBD), is not an intoxicant – tetrahydrocannabinol, or THC, is the stuff that gets you high. Nevertheless, US drug laws made it nearly impossible to get CBD at concentration in the US.

It had taken months of phone calls, emails and meetings with doctors and pharmaceutical company executives on two continents to get permission to try this drug. Sam wasn't joining an ongoing clinical trial. The company made the pills just for him. It believed CBD was safe based on animal studies. It also said it knew of about 100 adults who had tried pure CBD like this over the past 35 years. As a percentage of body weight, Sam's dose would approach twice what anyone else had tried for epilepsy. What would the side effects be? We didn't know. We'd volunteered our son to be a lab rat.

Then there was a bigger question: would the medicine even work? No one knew. The reason Evelyn, Sam and others in my family – including Sam's twin sister, Beatrice, and Evelyn's sister, Devorah – travelled to London during Sam's winter holiday was that two dozen other treatments we'd tried had all failed. (I stayed behind in San Francisco, scrambling to meet an end-of-year book deadline.)

The one thing we were certain about: this was not going to be a bargain. We'd already spent tens of thousands of dollars on consultants to help Sam's doctors set up the visit, and we were still at the starting line. The best-case scenario was that the medicine would work and eventually we'd be allowed to import it into the US. We secretly hoped that this would encourage the company to make the drug easily and cheaply available to others. We also knew this was quixotic. Our previous experience with medications suggested the whole venture would end in failure. This much we knew: importing an experimental cannabis-based drug into the US would involve more than giving the company my address and FedEx account number.

IF

you're the parent of a healthy kid, it's hard to imagine yourself doing what we did. Who spends tens of thousands of dollars on anything that's not a house, a car or college tuition? Who lets their child be the first, or even one of the first, to try any medication? But Sam was not a healthy kid. He has had epilepsy since he was four-and-a-half. We'd tried every possible drug – nearly two dozen medications – plus autoimmune therapy using intravenous immunoglobulin and a high-fat medical diet. (I wrote about our two-year diet experiment in *The New York Times Magazine*.) Little worked, and the treatments that did show results didn't work for long or had worrisome side effects.

Sam doesn't have grand mal seizures, where the sufferer collapses twitching on the ground. Instead, he partially loses consciousness for five- to 20-second bursts. It's a hard-to- treat variant of so-called absence epilepsy. The seizures themselves are more benign than grand mal, and they don't leave him exhausted. But they are much more frequent. When Sam's seizures are uncontrolled he can have between ten and 20 episodes an hour. That's one every three to six minutes and sometimes more than 100 a day.

To me, watching Sam have a seizure looks like a movie that's been paused and restarted. He stops and stares vacantly. His jaw slackens and his head and torso lean forward slightly, bobbing rhythmically. Then it's over, and he resumes as if nothing happened. If he stopped walking, he'll start again. If he was packing his backpack for school, he'll continue. Though Sam says that he is sometimes aware when he has a seizure, typically his only clue is that when he comes to, everything around him has shifted slightly.

When they are frequent – which has been often – it's hard for Sam to have a conversation, let alone learn anything in school. Sports? Not possible. As a little kid, Sam couldn't even cry without being interrupted: he'd skin a knee, cry for 15 seconds, have a 15-second seizure, and then continue

Sam Vogelstein has had epilepsy since he was four-and-a-half. He turned 14 in May

crying. Once, after watching a movie with me, he complained about the DVD being scratched. It wasn't. It just seemed that way because he'd had so many seizures.

And while Sam got little help from the many anti-epileptic medications that we tried, he endured plenty of side effects. One drug gave him hand tremors. Another made him violent. A third gave him hives. A fourth made him such a zombie that he drooled, and a fifth made him see insects crawling out of holes in his skin. Twice his seizures were bad enough that we had to hospitalise him. He'd seen six neurologists in three states. I've seen him seize tens of thousands of times. You'd think I'd be used to it, but I find each one haunting – as if some outside force has taken over his body, leaving me, the person who is supposed to protect him, powerless.

By 2012, when Sam was 11, the only thing that was keeping his seizures controlled enough for him to attend school was massive doses of corticosteroids: synthetic versions of the body's own anti-inflammatory compounds. Taken for a week or two, they can be lifesavers. But if taken for extended periods, they wreak havoc on the body.

By the time he reached London, Sam had been on a big dose of the corticosteroid prednisone on and off for a year. He put on 13kg. His face looked like it had been pumped full of air. He was starting to get head and chest colds every month. Were he to stay on these drugs at these doses longer-term, he would face stunted growth, diabetes, cataracts and high blood-pressure – all before he was old enough to vote. The trip to the UK felt like a last resort.

THIS

situation is hardly unique. About three million Americans have epilepsy, and about a third of them have epilepsy that can't be curbed with medication. More than a dozen anti-seizure drugs have come to market in the past 25 years, but the number of hard-to-treat cases of epilepsy like Sam's hasn't changed meaningfully in decades.

There are dozens of seizure disorders. Some cause patients to collapse like marionettes whose strings have been cut. Others cause a single limb to twitch. Big seizures can cause brain damage. And tens of thousands of people die every year from *status epilepticus*, a seizure that lasts for more than five minutes and typically requires a trip to the emergency room.

Think of a seizure as an overtaxed electrical grid. The human body is full of electricity that allows brain cells, nerves and muscles to communicate in an orderly, controlled fashion. A seizure happens when this electricity spikes uncontrollably. As a result, parts of the brain's circuitry temporarily shut down. You'd think medical science would be able to tell you why this happens and what to do about it, but with a few exceptions it can't.

Most epilepsy cases are like Sam's: idiopathic, a fancy way of saying "no known cause". A typical prognosis: if we can control the seizures with the first three meds, he'll probably never have another one. If we can't, the future is less certain. Beatrice developed absence epilepsy when she was older, in 2010. The first drug made the seizures disappear. She took it for two years. We have never seen another seizure.

There was nothing invisible or mysterious about Sam's epilepsy in London, however. By the time he and Evelyn arrived, his seizure count was approaching its highest level ever. We had expected this. We'd reduced one of the drugs helping to control his condition five days before they left. If the drugs in London worked, we'd need convincing data to get permission to import them into the US. To get convincing data, we'd need to show a marked reduction in seizures.

It was not easy to watch. Two days before departure he had eight seizures. One day before departure he had 25. The day of departure he had 20, including 12 in the 88 minutes between 5:50pm and 7:18pm, immediately after the flight to London took off. By the end of the next day, when they picked up Sam's pills at the Great Ormond Street Hospital pharmacy, his seizures had more than tripled to 68. Past experience told Evelyn that if the pills didn't work fast, the following day would be a complete wipeout with more than 100 seizures.

THE

first time Evelyn and I talked about cannabis as a treatment for epilepsy was in early June 2011. The high-fat diet Sam had been on for two years had stopped working. There were no more conventional anti-epileptic drugs to try. In our scramble to find solutions, Evelyn learned that a nurse-practitioner in one of our doctors' offices was starting a cannabis collective – outside of work – to help some of the physician's sickest kids. Other parents of epileptic kids we knew were joining. Besides having a medical degree, the nurse was a herbalist. She'd heard that cannabis – if made into oil-based tinctures, taken by the drop instead of smoked – could help people with intractable seizures.

We knew that if we were going to ditch western medicine to treat Sam's epilepsy, we'd have to do a lot more homework. Many people, often justifiably, hate drug companies. But one thing they are good at is making sure that every pill, drop or spray of medicine they supply is exactly the same. Treating Sam's epilepsy with cannabis would mean the reliability, consistency and potency of his medicine was no longer assured. I'd smoked plenty of weed in college and in my twenties. I knew the plant could have real medicinal effects; medical cannabis was legal to buy in California with proper documentation. But rightly or wrongly, the idea of treating Sam with cannabis – he was ten at the time – alarmed me.

By the time another year had passed, we were desperate. Intravenous immunoglobulin hadn't worked. And it was becoming increasingly less safe to control Sam's seizures with high doses of corticosteroids. In May 2012 we wrote a $600 (£400) cheque to join the cannabis collective. We knew to expect uncertainty. Plants as medicine are by their nature variable in potency. The nurse was still trying to figure out which strains worked best. And while some parents were

Sam's twin sister Beatrice's epilepsy disappeared after one week on medication

I KNEW THAT CANNABIS COULD HAVE REAL MEDICAL EFFECTS. BUT RIGHTLY OR WRONGLY, THE IDEA OF TREATING SAM, WHO WAS TEN AT THE TIME, WITH IT ALARMED ME

reporting good results, no one was seizure-free. But over the previous year we had also learned that treating epilepsy with cannabis wasn't crazy at all. A small but growing body of research suggested that CBD might be a powerful anticonvulsant. And then, remarkably, the first tincture we tried seemed to ratify those findings. For three days, Sam's seizures went from up to 20 an hour to about one an hour. The tincture was odd-looking – a bunch of cannabis leaves and stems in a brown mason jar marinating in oil. We'd put a drop of the liquid on Sam's tongue three times a day. It was supposed to be 20:1 CBD to THC.

In July, coinciding with a new tincture, Sam's seizures returned. By the middle of the month he was having around ten an hour. We tried increasing the dose. We tried tinctures bought at three medical cannabis dispensaries. They didn't work either. By mid-August we were thinking about putting Sam back on steroids. That was when the collective received test results for the latest batch of tinctures. They'd been advertised as having a 20:1 ratio of CBD to THC, but it turned out there was little CBD or THC in any of them. We also tested one of the other tinctures we'd bought from a supposedly reputable supplier. We'd been told it was 10:1. It was 3:1. The tincture that worked for Sam in June hadn't been tested, so we had no idea how to assess the temporary drop in seizures.

This was infuriating and frustrating. We knew the collective was still finding its way, but we'd convinced ourselves that it had mastered the basics. We only had ourselves to blame, though. We didn't have the tinctures tested either.

SOMETHING

else was happening throughout the spring and summer of 2012 which I only found out about much later. Evelyn had started wondering how to contact the head of a drug company in the UK. She'd been thinking a lot about an article in *Seizure*, the medical journal of the British Epilepsy Association, which documented how pure CBD slowed seizures in rodents. But it wasn't just the encouraging results that caught her eye. It was the authors, all researchers at the Schools of Pharmacy and Psychology at the University of Reading, one of the UK's top research institutions. She noted that they had thanked GW Pharmaceuticals, a British company, for funding the study.

GW, we soon learned, manufactured pharmaceutical-grade extracts of both THC and CBD. Its main business came from a drug called Sativex, which contains a mix of the two compounds in a mouth spray for sufferers of cancer pain or multiple sclerosis. But it also seemed to have supplied pure CBD to the authors of the *Seizure* study.

For Evelyn this was revelatory. CBD was the only thing left that might help control Sam's seizures. And over in the UK there was a drug company making the stuff. The next move was obvious: find out who ran GW – she quickly determined that his name was Geoffrey Guy – and get in touch.

My dad's firm, Warburg Pincus, had been doing business in London for 25 years so he emailed some associates, detailing Sam's situation. Eleven days later Geoffrey Guy wrote to Evelyn asking how he could help. Later that day he told Evelyn on the phone that figuring out a way for Sam to try GW's CBD was eminently possible.

It turned out that the kind of one-patient experiment we were suggesting wasn't unheard-of in the UK. Doctors there can get promising medications for their patients from the manufacturer to be used under their direct responsibility. It's known as administering on a named-patient basis. No regulatory approval is required as it is in the US. Guy said he'd done it with more than a thousand patients.

The catch was that GW would only help us if we did it above board. We'd have to go to the UK. We'd need our US doctor's permission. We'd have to find an epilepsy doctor in London to take our case and to agree to supervise treatment and tests.

And if the medication worked, we'd need to navigate a labyrinthine approval process to get the drugs into the US. The research ethics committee at our doctor's employer, UC San Francisco (UCSF), would have to approve our plans to administer the medication at the hospital. The US Food and Drug Administration (FDA) would need to sign off on what we were doing. We'd heard that the FDA applications were hundreds of pages long. And we'd need clearance from the US Drug Enforcement Administration (DEA). Despite legalisation efforts in some states, it's the federal government that controls the borders, and to get any illegal drug across the border you must get approval from the DEA.

The magnitude – and the cost – of our undertaking was daunting. Just travelling to London, staying for two weeks and paying doctors' bills would run into the thousands. We'd have to hire consultants to draft our applications to the FDA and DEA. Our doctor hadn't done anything like this before. The only way she was going to be able to get behind it on our behalf was if we handled all the paperwork for her.

WE

met Geoffrey Guy face-to-face in a conference room off the neurology waiting room at UCSF. We were dressed like we lived in California. Guy was dressed like an early-20th-century English banker. He wore a double-breasted suit, a white-collared blue shirt with French cuffs and a yellow tie with blue polka dots. Evelyn and I had been exchanging emails with him since the end of August 2012. Now, in early December, we were sitting down to discuss some last-minute details of our London trip. The meeting was also an opportunity for Guy to talk to Sam's new doctor, Roberta Cilio. Sam's longtime neurologist had had to take an emergency leave of absence the week before. Cilio, an eminent Italian physician who had only joined the staff of UCSF the previous September, was jumping into the middle of an unfamiliar case. We were meeting her for the first time too.

We knew little about Guy at that point other than the essentials: he was a longtime biotech entrepreneur, and he had an experimental compound that, turned into a drug, might help Sam. We learned later that he'd started three notable drug companies and brought more than a dozen medicines to market. He knew more about cannabis than almost any executive in the world. And in more than 30 years as a biotech CEO he had built a reputation as a maverick – someone attracted to the thorny, controversial pharmacological issues that most executives try to avoid. Guy had been thinking about starting a company to make medicines from cannabis since the early 90s.

Back then, regulators in the UK said they would never approve it. But by the middle of the decade, the British political landscape had began to shift significantly. The courts were clogged with the cases of multiple sclerosis and cancer patients who'd been arrested for using cannabis to combat things such as muscle spasticity and the symptoms of nausea from chemotherapy. Politicians and activists were calling for partial legalisation.

And so, in July 1997, Guy found himself at a joint conference of the Royal Pharmaceutical Society and the Multiple Sclerosis Society. Onstage, top UK doctors and regulators were wondering aloud what it would take for a company to make a cannabis pharmaceutical. Guy raised his hand and explained how he thought it could be done. A year later, in June 1998, Guy and co-founder Brian Whittle got permission to start GW. "It was like a wormhole opened up and we'd spent the previous ten years studying wormholes," Guy says.

By 2012, GW was one of only a handful of firms in the world doing legal, drug-company-quality research on cannabis. It owned huge hothouses containing thousands of cannabis plants in legal but undisclosed locations south-east of London. It had labs converting the plants into medicinal extracts and a factory that could turn them into sprays, tinctures and pills. It had 177 employees and $51 million in revenue. And it was manufacturing its first drug, Sativex, approved for sale in the UK, Canada and 22 other countries to treat MS.

Back in the UCSF conference room, we finalised our plans: Evelyn would take Sam to London, where he would try pure CBD pills made especially for him. He wouldn't be the first person to try pure, pharmaceutical CBD for epilepsy. Four small studies between 1978 and 1990 had tried it on a total of about 40 people. Surely others had tried homemade concoctions. But he'd certainly be the first kid, and arguably the first person in more than 20 years, to try CBD of this purity for epilepsy. We hoped it would work for Sam and that many other patients like him would follow.

SETTLING

into London, Evelyn was almost afraid to believe how well the treatment seemed to be working. After having 68 seizures on Thursday, the day Sam and Evelyn spent at Great Ormond Street Hospital, Sam had ten on Friday and five on Saturday, ten on Sunday and six on Monday. She increased the dose of CBD from 50mg to 250mg a day and his seizure count continued to fall. They didn't see any side effects.

Sam's seizures decreased so quickly – in less than 24 hours – that two days after taking his first pill he was zip-wiring, harnessed, ten metres in the air above a carnival in Hyde Park.

At first we said nothing to family or friends. We worried that, like so many promising treatments we'd tried, the effect would be only temporary. But by December 28, 2012, eight days after Sam's first pill, it was obvious that we were witnessing something fantastic. "Best day yet," Evelyn wrote to friends and relatives. "Today Sam had a total of three seizures – short, seconds-long. From our starting point of SIXTY-EIGHT seizures. I would say we are doing very well. And we can go higher on the dose if we like. Along with being nearly seizure-free, Sam is more mature, more relaxed and funnier. No idea if that is a physiological effect or just a result of not having his train of thought interrupted all the time, but who cares... I love to see all that come out."

Our euphoria lasted two weeks. The trial was ending, and Guy wasn't going to let us take any CBD back to the US. On January 2, 2013, he emailed Evelyn telling her that he'd be sending one of his executives to the hotel to pick up any unused pills. We knew to expect this, but it was still excruciating. Two weeks into enjoying the best seizure control of Sam's life, we were being asked to give back the medicine that got him there. We had cobbled together a plan to manage Sam's seizures during the time it would take us to obtain permission and co-operation from UCSF, the FDA and the DEA. We hoped that would happen in less than six months, as we'd been told. But no one knew for sure. When you've found the first medicine in seven years that controls your child's debilitating illness, not having it for an hour feels too long.

What we used to control Sam's seizures during that time seems irresponsible in retrospect. A few weeks before we left for London we'd found an outfit in Colorado that claimed to make CBD pills from hemp. They seemed to help Sam a bit, and the company was willing to send the pills through the mail. Testing showed a CBD-to-THC ratio of 18:1, but we didn't know whether their manufacturing process was clean. A month's supply cost more than $1,000. At the time it seemed better than putting Sam back on steroids.

The agents from the DEA appeared without an appointment at Cilio's UCSF office door on March 1, 2013. They showed her their badges, asked permission to question her, and made it clear that this was not going to be a friendly conversation. "They asked a lot of personal questions," she says. "Where was I from? Had I ever used illegal drugs?"

The questioning, which went on for two hours, got particularly tense when the agents asked Cilio how she planned to dispense the special drug. "I said that I would keep it here in my office and then put it in my purse and walk across the street to the clinic to see my patient. And they said, 'You have no idea what you are talking about. This is a Schedule I drug. It's like heroin. You can't cross the street with it in your bag. You have to keep it in your office, and you have to give it to the patient in your office.'"

As part of the special licence application process, she'd been briefed by UCSF security and demonstrated to the agents that she understood how the locks and alarms worked in her office suite and building. They weren't satisfied. They took pictures of the furnishings in her office, including the cabinet she told them she was going to store the medicine in. They told her she would need a safe.

I was both elated and panicked when I heard about the agents' interview. Setting up a site visit by agents is notoriously slow. Our application had been live for only about eight weeks. But I worried the demand for a safe would suck our application into a bureaucratic quagmire. I thought I could just buy a cheap jewellery safe. I was wrong. According to government regulations, the safe needed to be certified for "30 man-minutes against surreptitious entry; ten man-minutes against forced entry; 20 man-hours against lock manipulation; and 20 man-hours against radio-

Sam now fences three times a week and played for the school's indoor football team

logical techniques". In English: a one-metre-square steel box that weighs 400kg and looks like something Road Runner used to drop on Wile E Coyote.

It turns out that used safes are not hard to find. Cilio said that if I bought one, she'd gladly put it in her office. UCSF officials said it was OK as long as the safe didn't violate building load limits. Within a day I was the proud owner of a used blue Meilink TL-15 plate safe with a group 1R lock. I had it delivered to Cilio's office. The cost for unravelling this bureaucratic knot: $2,100.

THE DEA AGENTS APPEARED WITHOUT AN APPOINTMENT AND MADE IT CLEAR THAT THIS WAS NOT GOING TO BE A FRIENDLY MEETING

DEA approved our application on March 19. Between getting import permits, clearing customs and Cilio's unrelated attendance at an overseas conference, another six weeks passed. Sam took his first CBD pill in the US on May 4, three weeks before his 12th birthday.

The total bill for getting GW's CBD into the US was roughly $120,000, excluding travel. Two consulting firms – one an expert in the workings of the FDA, the other an expert in the DEA – generated most of those expenses. It's an enormous amount of money, but it's hard to imagine how we could have done it without them. They helped Cilio with the mountain of paperwork and worked their FDA and DEA contacts to make sure our application kept moving. Despite their initial antagonism, the DEA agents also moved our application along quickly when we met their demands.

We wouldn't have even known that consultants did work like this had Steve Willard, a Washington, DC, drug company entrepreneur, not introduced us to them. Sam now says he's his best adult friend, even though he was my dad's friend first.

Usually, getting access to experimental drugs that are potentially lifesaving doesn't work this way. With terminal-cancer patients, for example, oncologists know what new drugs are in development and have a mechanism already established to work with a company and quickly get FDA approvals. Yet GW was supplying drugs that were illegal in the US. No US hospital would take on a project like this.

But it appears our enormous bill for helping Sam has also jump-started the development of what doctors tell us could be one of the most exciting new drugs to treat epilepsy in a generation. Within a month of our return from London, Guy and GW started talking to epileptologists at four other US hospitals about doing studies with their sickest kids. And on January 26 in New York City, 15 doctors, researchers inside and outside the US government and GW officials sat in a conference room at NYU and began mapping out a strategy.

Those initial investigations – five hospitals, 25 kids apiece – proved so encouraging that GW in 2014 expanded them to what it expects will be 1,400 patients at more than 50 hospitals in the US and the UK by year's end. The drug now has a name – Epidiolex. (Guy thought about naming it after Sam.) It has a fast-track designation from the FDA, meaning that it could be available on the high street within three years.

Epidiolex is not a miracle cure. The most recent data, out in April, shows that of 137 kids who tried it for 12 weeks, it helped about half, reducing their seizures by at least 50 per cent, with nine per cent becoming seizure-free. This is better than it sounds. All of the patients in the trials had run out of conventional options. It is also a reminder that CBD, Epidiolex or any seizure drug doesn't help everyone.

Today CBD's potential for treating epilepsy has become an important story in medicine. In August 2013, Sanjay Gupta, CNN's chief medical correspondent, reported on a cannabis strain that had all but cured Charlotte Figi, a five-year-old girl with Dravet syndrome, one of the worst kinds of epilepsy. Figi was in a wheelchair, on a feeding tube, with a do-not-resuscitate order before her parents started experimenting with high-CBD cannabis in 2012. The oil, supplied by a group of evangelical Christian brothers in Colorado Springs named the Stanleys, helped her almost immediately. Figi quickly went from 300 grand mal seizures a week – an average of 40 a day – to about four a month.

Three cannabis documentaries on CNN and a week's worth of editorials in *The New York Times* in 2014 have ignited a national conversation not just about CBD for epilepsy but also legalising cannabis entirely. Twenty-three US states have legalised it for medical use, 18 states have decriminalised recreational use too, and four states have made recreational use completely legal. At least five other states, including California, are expected to put legalisation to a vote in 2016. And bills in Congress to change the laws on a federal level, which would make it easier for researchers to study cannabis in the lab, are finally getting traction.

Edward Maa, a neurologist at the University of Colorado, Denver, is doing the first study of the Stanley brothers' strain, now called Charlotte's Web, to get data on its effectiveness. He has 14 Dravet patients so far. The Stanleys now ship Charlotte's Web across state lines, because the cannabis has so little THC that it is considered hemp. The operation has 3,508 customers, about a third of them kids with epilepsy.

Little of this was happening four years ago, when Evelyn and I first started using cannabis and epilepsy in the same sentence. Watching Sam's life unfold alongside it has been profound. He now has between zero and five seizures a day, and he's been off all other anti-epileptic medications for almost two years. GW makes Epidiolex as a liquid now. Sam takes 3.5ml at breakfast and dinner. He is, perversely, more frustrated by his episodes now than when he was seizing every few minutes. Back then he was in a fog. Now, because he is so close to being seizure-free, he feels each disruption more keenly. He increasingly understands that if we can't get the remaining few to go away, he won't be able to drive a car or ride a bike.

But for the first time in a decade he is living like a normal boy. He takes a bus and a train home from school every day. He's studying to be a bar mitzvah next year. He plays *Halo* at his friend Brian's house on Friday afternoons. Before school broke up for the summer, he was doing more sports than he had time for. He could barely run 100 metres without seizing three years ago. Last summer we went fly fishing and rock climbing. He makes up songs in the morning before school.

Most of us spend our childhood blissfully thinking that our parents can solve most of the big problems we face. Sam had to find out way too early that sometimes that's just not true. I hate that he had to learn that lesson so soon. I hope surviving it will give him the inner strength to better handle life's other beanballs.

All of this makes me recall a conversation I had in 2009 with Doug Nordli, an eminent Chicago epileptologist. He made a point of saying that, as hard as we might find it sometimes, the one thing we should never do is become hopeless about Sam's seizures. This wasn't just a pep talk. He said that he'd seen kids like Sam rebound with astonishing speed once their seizures were brought under control. I wanted to believe him, but back then I just couldn't. Now I see proof every day of how wrong I was. W

Fred Vogelstein is contributing editor to US WIRED and author of Dogfight: How Apple and Google Went to War and Started a Revolution *(William Collins)*

OVERHEARD AT WIRED THIS MONTH
"What's the world coming to when you can't get a dinosaur-riding Batman action figure in a magazine aimed at discerning adults?"
"But are they innovating sandwiches?"
"Are they ever!"
"I liked it, but it was so close to being bad, I didn't know if I really did like it."
"I'm scared and excited at the same time. It's very *Fifty Shades*" – staffers discussing a cover. (Make your own mind up next issue.)

FORGETFULNESS THIS MONTH
The world memory champion forgot he was being interviewed by WIRED this month. And the writer also forgot to tell the picture desk that he'd need a photographer for the meeting. Let's hope we at least remembered to send this feature to the printer...

REJECTED HEADLINES THIS MONTH
"Brain helmet of the month"
"What a piece of junk!"

PEGG-CAM THIS MONTH
Our cover star wore a GoPro HERO4 during his shoot for WIRED – so of course we switched it on and left it running. To watch highlights of Simon Pegg's day, download our app.

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CLUBBING THIS MONTH
WIRED's younger staff enjoyed a special DJ set by the Boiler Room (see p62). Those over 30, who were not waving their hands in the air like they just don't care, were in bed.

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Vogue, GQ, Vogue Girl, Wired, Vogue Wedding

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Vogue, GQ

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THE WIRED INDEX

17 million

UK adults with numeracy levels equivalent to those of primary school children, according to the Department for Business, Innovation and Skills

18%

The increase in flu deaths of people over 65 years old, when their local team made it to the Super Bowl final, according to a study done at Tulane University

10%

Increase in domestic violence among supporters of the losing Super Bowl team, if they were predicted to win, according to a University of California at Berkeley study

2.4

The maximum number of hours it is recommended you spend jogging each week to achieve optimal life expectancy according to a study conducted over 14 years by the Copenhagen City Heart Study

THIRTY-FIVE

The number of questions used by the American National Counterterrorism Center in Washington, to assess whether someone is at risk of becoming a terrorist. They are listed in its guide, *Countering Violent Extremism*

$50

How much it costs to adopt a Madagascar hissing cockroach or an Arizona Desert hairy scorpion at San Francisco Zoo

1.97

How many times more likely you are to die if you are considered a strenuous jogger – that's speeds of over 11kph, for four hours each week, or at least 2.5 hours divided over at least three sessions – compared to being a non-jogger, according to the same study

487 bytes

The size of *BootChess*, the smallest computer chess game, designed by French coders Red Sector Inc, in 2015

672 bytes

The size of the previous record-holding chess game, *1K ZX Chess*, which held the tiny crown for 33 years

$60

Costs for one night at the Japanese Huis Ten Bosch theme-park hotel in Nagasaki, which is staffed by ten humanoid robots (more "staff" are in the works)

0.22

How many times more likely you are to die if you are considered a light jogger – that's speeds of about 8kph, for durations of 2.5 hours or less, over no more than three sessions – compared to being a non-jogger, according to the same study

8.6 megabytes

Size of the *Chess* application that comes pre-installed on Apple computers

€54,000

Amount Finnish businessman Reima Kuisla was fined for breaking the speed limit. In Finland, such fines are calculated based on income

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